



**Environmental Considerations in  
Energy Development  
India Country Study**

**Final Report**

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## **EXECUTIVE SUMMARY**

India is an oil importing developing country as well as an energy supply constrained economy whose environmental resources have degraded perceptibly in the last two decades. With rapidly increasing energy needs, it is imperative to meet development goals minimising undesirable social, economic and environmental consequences. Based on these considerations, this study has developed an optimal energy strategy for India to the year 2010.

Coal is India's major energy resource. As of 1990, proven and indicated coal reserves were estimated at 138 billion tonnes of which 27 billion tonnes was coking coal and the balance comprised non-coking coals, predominantly of inferior grade (high ash). The annual production was 209 million tonnes (MT). As of 1990, the proven and indicated balance recoverable reserves of crude oil and natural gas were only 757 MT and 686 billion cubic metres respectively. Currently, production of crude oil is around 31 MT per annum, meeting approximately 61% of the total requirement. Based on available data, the total 'economically' exploitable hydroelectric potential is 396.4 TWh of annual energy generation (75,400 MW at 60% load factor). Only one-fifth of this potential has been developed. Three-fourths of the population continues to depend on locally available biofuels that account for approximately 40% of the total energy consumption.

Growing industrialisation and urbanisation have contributed to a deterioration in air and water quality. Cities are heavily stressed, with total suspended particulate levels exceeding the ambient standards in several cities. In this context, Delhi, the capital of India, is now one of the world's most polluted cities. The discharge of industrial effluents and domestic sullage, mostly untreated, into rivers has resulted in water quality far below acceptable levels. Forest resources have declined over the years. Increasing population is not only adding to the demand for forest products but also for agricultural land which results in the clearing of forests. Based on 1987 imagery, only 19.47% of the country's geographical area was under forest cover, in comparison with the government's objectives of 33%.

Against this backdrop, the study explores three energy strategies to the year 2010. These are:

### Business-as-usual (BAU) strategy

Based on current government thinking, this strategy forms the reference against which the alternative strategies are compared.

### Strategy I

An environmentally superior strategy to the BAU, this is based on specific energy conservation measures for improving the efficiency of energy production, conversion and end-use along with energy demand management and technology changes.

### Strategy II

Again an environmentally better strategy than the BAU, this is based on a greater utilisation of more environmentally benign energy forms, that includes the augmentation of power generating capacity by renewable energy technologies, and penetration of renewable energy forms and environmentally benign energy uses on the demand side.

The two strategies comprise mutually exclusive options and therefore cannot be compared directly. However, if both are found to be desirable, a combination strategy consisting of the components of both the strategies can be readily evaluated.

For each of the strategies, economic costs are evaluated. These include direct costs (equipment, labour, various inputs) valued in economic terms, and environmental and social costs across the energy cycle, i.e. from extraction to end-use. For evaluating environmental impacts over a region, an attempt is made to capture locational aspects, since a given level of discharge (emissions/effluents) will cause greater environmental damage in environmentally stressed areas than in relatively clean areas. This feature is incorporated for airsheds, where the airshed in a region is classified into three zones, based on the level of stress. Environmental costs are valued by indirect techniques using two approaches -- preventive expenditures and changes in productivity. However, data and methodological limitations made it difficult to place a monetary value on all impacts. Impacts valued are the emissions from thermal power plants of total suspended particulates, sulphur dioxide, oxides of nitrogen, and forest loss due to submergence from hydro projects and coal mining. Environmental impacts not valued include impacts from the transport and industrial sectors. These have been assessed using the multi-attribute assessment approach. Since only air emissions have been quantified for these sectors, the assessment is limited to 'airsheds'.

The exercise is conducted for two scenarios, characterized by GDP growth rates of 5% and 6%. The annualised costs (US\$ million) in the year 2010 for the BAU strategy are 181,097 and 209,280; for strategy I are 143,595 and 164,108; and for strategy II are 180,588 and 208,787 for the 5 and 6 per cent GDP growth scenarios respectively. The multi-attribute assessment is done in terms of 'damage equivalent' emissions for air as a whole for the year 2010. The 'damage equivalent' emissions takes into account the damage potential of the three zones and the individual pollutants, and for the BAU are (in '000 tonnes) 18,215 and 25,815; strategy I are 8,450 and 9,486; and strategy II are 18,206 and 25,806 for the 5 and 6 per cent scenarios respectively. As can be seen both strategies are superior to the BAU, and therefore the combination strategy, which consists of energy conservation measures and a greater use of more environmentally benign energy forms is the best overall strategy. This is also seen from the results where the combination strategy has annualised costs (US\$ million) of 143,268 and 163,601 and 'damage equivalent' emissions ('000 tonnes) of 8,441 and 9,477 for the 5 and 6 per cent growth scenarios respectively; both are the lowest in terms of total costs and unvalued air pollution.

A summary of the measures of the combined strategy are given below along with recommendations on institutional changes that would be required if this strategy is to be implemented.

## **Energy conservation**

### **Transport sector**

(1) Improved highway construction and maintenance. Not only does this option result in better energy efficiency but also in reduced pollution, reduced maintenance costs, etc. It is estimated that till the year 2010, this option would require US\$ 8.7 billion. This level of investments and improvement in services can be brought about by involving the private sector on a contractual basis.

(2) Investments in urban rapid transit and metro facilities. The strategy considers metro systems for two mega and seven metropolitan cities needing an average investment of US\$ 1.3 billion per metro system. This can be met realistically from external sources only. For quick and efficient implementation the build-operate-transfer (BOT) concept should be explored.

(3) Shifting of transport from roadways to railways. This would entail a major technological upgradation in the infrastructure and operations of the railways. This can only be brought about by major changes in the organisational set-up, by converting the zonal railways into separate public sector undertakings with greater autonomy, which would permit faster decision-making in attracting funds from the market for specific projects.

#### Industry

Conservation measures in three industries, namely iron and steel, cement, and chemicals and petrochemicals are considered in this study. Although energy conservation is economically attractive, the speed of implementation can be enhanced by dissemination of know-how and increased facilities from financial institutions to deal with energy conservation projects. Additionally, to increase co-generation facilities, legislation of the PURPA type would be required.

#### Domestic

Appliance efficiency improvements, specifically lighting and refrigeration are considered. Introduction and implementation of appliance standards, and improvement in the quality of power supply will enhance the usage of more energy efficient appliances.

#### Agriculture

Retrofitting of existing pump-sets and use of more energy efficient pump-sets are considered. Improvement of pump-sets can only be brought about by laying down efficiency standards. The heavy subsidy for irrigation pumping results in inefficient use of energy, and therefore the pricing of electricity needs to be addressed in this sector.

#### **Renewable energy technologies**

##### Wind

Wind farm capacity additions of 3000 MW is realisable till the year 2010 by the private sector and the utilities. Here again, legislation of the PURPA type would be required.

##### Small-hydel

Small-hydel capacity is also seen to be a viable option and a capacity of approximately 1500 MW is a realisable target till the year 2010. The standardization of the hydroelectrical equipment would insure better reliability and reduced costs.

### Other technologies

These include biogas and solar cookers, the latter to be directed at semi-urban and peri-urban areas where fossil fuels are limited and fuelwood is commercialised.

### Alternative energy forms

Compressed natural gas: A limited number of cars, buses and trucks using CNG is seen to be a viable option in several cities close to the existing gas pipeline network.

### **Measures on the entire energy system**

#### Natural gas

The study projects a production of 53 bcm in the year 2010 which is completely absorbed in the BAU strategy. It would be useful to explore options for import of natural gas by pipeline from countries such as Bangladesh and Iran.

#### Oil

The study shows an import level of 54 MT per annum in year 2010 under the combination strategy. In order to close the gap by increasing production, the hydrocarbons industry must gradually move towards privatisation and develop policies for attracting foreign companies into oil exploration.

#### Coal

Results show coal production and usage to rise over 500 MT in the year 2010. This would require a rapid expansion of the coal transportation and distribution system. Results also show the economic viability of coal washeries. This needs to be vigorously pursued.

#### Power

In order to close the gap between electricity demand and supply (117 GW of additional capacity to be installed till 2010) early steps are essential to attract private sector participation. This can only be brought about by throwing open an entire region for generation, transmission and distribution, to be followed later in other regions.

#### Rural energy sector

Biofuels will continue to dominate the rural sector. Therefore, priority should be given to the enhancement of energy supply options such as afforestation and wastelands development along with the dissemination of biomass based efficient technologies. Since biofuels are locally available, rural energy programmes must have a decentralised approach.

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## BACKGROUND

The production and utilisation of energy affects the environment to varying degrees of intensity depending upon the patterns of energy consumption, technologies and economic/environmental policies. Uptil recently, energy planning was devoid of any environmental considerations. However, with the growing realisation that a healthy environment is not only crucial for mankind's survival in the longer term but also has an immediate bearing on the quality of life, it is imperative that environmental aspects be integrated in energy planning. It is this exercise that this study undertakes for India.

India is a large country with substantial regional variations in energy supply and demand. A multi-regional approach is necessary to address these issues adequately. Environmental impacts have local, regional and global ramifications, with the local impacts demanding even a greater level of disaggregation.

The terms of reference for this study defines a multi-regional approach that divides India into five regions. Based on those currently used for power sector planning. These are :

- North : Haryana, Himachal Pradesh, Jammu & Kashmir, Punjab, Rajasthan, Uttar Pradesh, Chandigarh, Delhi.
- West: Goa, Gujarat, Madhya Pradesh, Maharashtra, Dadha & Nagar Haveli, Daman & Diu.
- South: Andhra Pradesh, Karnataka, Kerala, Tamil Nadu, Lakshadweep, Pondicherry.
- East: Bihar, Orissa, West Bengal, Andaman & Nicobar Islands.
- North-East: Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura.

Based on this grouping, the study examines a Business-as-usual (BAU) energy strategy and two environmentally better strategies for the period 1990-2010. Each strategy is evaluated as follows:

- \* Projection of energy supply and demand, and description of technologies that define the energy strategy.
- \* Determination of environmental impacts emanating from the energy strategy.
- \* Economic evaluation of the energy system.
- \* Economic evaluation of the environmental impacts or alternatively, where such an evaluation is not possible, a multi-attribute analysis.
- \* Selection of the least "cost" strategy based on least technology costs and least environmental damage.

The report is organised in nine chapters.

Chapter I provides an overview of environmental resources and energy resources and reserves.

Chapter II describes energy demand projections for the BAU strategy.

Chapter III describes energy supply projections for the BAU strategy.

Chapter IV evaluates environmental impacts emanating from the BAU strategy.

Chapter V discusses measures to mitigate adverse environmental impacts.

Chapter VI describes alternative energy development strategies.

Chapter VII describes the economic analysis (technological and environmental) of alternative strategies.

Chapter VIII presents the multi-attribute analysis and overall ranking of the strategies.

Chapter IX describes the conclusions and recommendations for implementing the most desirable strategy.





# C H A P T E R

## 1

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### Resource endowment

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#### Environmental resources

##### Physical features

Bounded by the Himalayas in the North, India stretches southwards and tapers off into the Indian Ocean with the Bay of Bengal in the East and the Arabian sea in the West. Lying between  $8^{\circ}4'$  and  $37^{\circ}6'$  North latitude and  $68^{\circ}7'$  and  $97^{\circ}25'$  East longitudes, the land mass which forms the subcontinent of India covers an area of 329 million hectares (mha) with a population of 843 million. It has a land frontier of 15,200 kilometres (km) and a coastline of 6083 km (7516.6 km including the islands).

Physiographically, India can be divided into seven divisions. These are the Northern Mountains, the Great Plains, the Central Highlands, the Peninsular Plateau, the East Coast Belt, the West Coast Belt and the Islands. The Himalayan range, 2500 km long and 250-400 km wide, with a mean elevation of 6000 metres in the central axial range, is the dominant geographical feature of India. The quality and quantity of natural resources should ideally be described on the basis of the physiographic regions. However, the analysis that follows in the remaining chapters is based on the five regions demarcated by the power planners. Therefore, we have chosen to describe natural resources on the latter basis. This will help in linking energy-environment issues of these five regions with their respective natural resources endowment.

##### Land use pattern

Out of the total geographical area of 329 mha, land use statistics are available for approximately 305 mha, constituting 93 per cent of the total area. The regionwise land utilisation in the country is indicated in Table 1.1. As can be seen from the table, over 41% (136.2 mha) of the total land area is under agriculture. Forests occupy an area of 20.3% (66.8 mha) and the balance 32 per cent of land is under miscellaneous uses.

### 1.1.3 Forest resources

The area officially recorded as forest (recorded forest area), by the Forest Departments is of the order of 75.18 mha [22.8% of the total geographical area (GOI, 1988a & 1990b)]. Recorded forest area is only a legal classification and includes all areas which have by law been defined as forest. Such areas may have tree vegetation or may consist of degraded and scrub lands only. Thus recorded forest may not entirely consist of tree cover.

**Table 1.1. Regionwise land utilisation in India (1987-88)**

Land use	Area (Million ha)				
	All India	Northern Region	Western Region	Southern Region	Eastern Region
1. Forests	66.858*	11.489	21.409	12.096	10.2
2. Area not available for cultivation					
(a) Area under non-agricultural uses	20.809	5.156	4.559	5.536	4.2
(b) Barren and uncultivable land	20.391	4.772	6.645	3.700	1.6
3. Other uncultivated land (excluding fallows)					
(a) Permanent pastures and other grazing land	11.848	3.542	5.019	2.153	0.8
(b) Land under miscellaneous tree crops and groves not included in net area sown	3.535	0.691	0.339	0.782	1.0
(c) Cultivable wastelands	15.626	7.429	4.709	1.728	1.0
4. Fallow lands					
(a) Fallows other than current fallows	11.134	3.903	2.216	2.747	1.4
(b) Current fallows	18.471	7.081	2.337	5.545	3.0
5. Agriculture (Net area sown)	136.177	37.395	46.981	29.179	18.8
6. Total reporting area	304.849	81.458	94.214	63.466	42.5
7. Area for which no returns exist	23.877	19.614	0.932	0.164	0.1
8. Total geographical area	328.726	101.072	95.146	63.630	42.6

Source: Government of India (1990a)

\* Figure pertains to land use statistics, and therefore differs from Forest Department mha.

Estimates of actual forest cover (based on landsat imageries) put it as only 64 mha (GOI, 1990b). It is this value that is of importance from an environmental viewpoint. The recorded forest area is only a legal classification and does not give any indication of the real cover of forest vegetation, its spatial distribution and the changes in its cover over a period of time.

The regionwise distribution of recorded forest area, as well as figures for the actual forest cover as per the 1987 and 1989 assessments, are as shown in Table 1.2.

**Table 1.2.** Forest land and forest cover in India

Region	Recorded forest area (mha)	1987 Assessment (1981-83 imagery) ----- Actual forest cover (mha)	1989 Assessment (1985-86 imagery) ----- Actual forest cover (mha)
(1)	(2)	(3)	(4)
Northern	12.9173	7.9110	8.2365
Western	23.9502	19.0257	19.0426
Southern	13.5956	11.1248	10.7875
Eastern	10.7808	9.8325	9.0089
North-eastern	13.9407	16.3101	16.9379
	-----	-----	-----
All India	75.1846	64.2041	64.0134
	-----	-----	-----

Source: GOI (1988a & 1990b)

1. Forest cover density: Whereas the outer Himalayan forests and evergreen forests of the West Coast and North-east are fairly well stocked, large areas in Central India, Indo-Gangetic plains, the coastal strips and other fertile valley systems are stocked either partially or are entirely devoid of forests. Of the actual forest cover of over 64.01 mha, only 37.8470 mha are of adequate density (crown density 40% or more) while little over 25.74 mha are open forests with crown density varying from 10 to 40%. Over 0.42 mha constitute the mangroves. Thus, the effective forest cover (37.8470 mha- 1989 assessment) in the country is limited to 11.51% of its geographical area, which is far below the figure of 33% envisaged in forest policies formulated in 1954 and 1988 (GOI, 1952 & 1988b).

The distribution of actual forest cover by various regions is shown in Table 1.3.

Table 1.3. Density of forest cover in various regions (mha)

Density class	All India	Northern Region	Western Region	Southern Region	Eastern Region	North-eastern Region
Dense Forest (Crown Density above 40%)	37.8470 (11.51)	4.3697 (4.32)	12.4009 (13.03)	6.8355 (10.74)	5.0823 (11.91)	9.1586 (34.93)
Open Forest (Crown Density 10 to 40%)	25.7409 (7.83)	3.8668 (3.83)	6.5888 (6.92)	3.9068 (6.14)	3.5992 (8.44)	7.7793 (29.67)
Mangroves	0.4255 (0.13)	- (0.00)	0.0529 (0.06)	0.0452 (0.07)	0.3274 (0.77)	- (0.00)
Total	64.0134 (19.47)	8.2365 (8.15)	19.0426 (20.01)	10.7875 (16.95)	9.0089 (21.12)	16.9379 (64.60)

Note: Figures in brackets indicate percentage of the geographical area of the region.

Source: GOI (1990b)

1.1.3.2 Forest types: The extensive distribution of forest over the Indian subcontinent is accompanied by considerable diversity in their specific composition. Accordingly, the forests of the country have been divided into 16 type-groups (Champion and Seth, 1968) ranging from Tropical Wet Evergreen forests to Alpine types with the Tropical Deciduous types (both moist and dry) constituting the bulk (65.48%) of our forests. Nearly 8% of the actual forest cover consists of Tropical Wet Evergreens.

While Tropical Moist Deciduous forests occur in all the five regions, their incidence is high in the Western (over 8 mha) and North-eastern (over 5 mha) regions; the Tropical Dry Deciduous type being totally absent from the latter. There are no Wet Evergreen forests in the Northern region whereas they predominate in the Northeast. Mangroves are confined to the Western, Southern and Eastern regions. Subtropical, Temperate and Alpine types are spread in almost all the regions with a predominance in the Northern and North-eastern regions.

1.1.3.3 Growth and yield: The growing stock of the actual forest cover in Indian forests ranges from as low as 10 cubic metres ( $m^3$ ) per ha in Rajasthan (Northern region) to as high as 277  $m^3$  in the coniferous forests of Kulu valley (Northern region). The average growing stock (65  $m^3$  per ha) compares poorly with the world average of 110  $m^3$  per ha (GOI, 1988a & b).

1990b). The total estimated growing stock of wood in the country is placed at 4,196 million m<sup>3</sup> while the recorded production of wood (timber and fuelwood) during the last 10 years has varied from 26 million cubic metres (mcm) to 32 mcm; average annual production being of the order of 30 mcm. Unrecorded production in the form of dead/dying and annually fallen wood, which is removed as head-loads for domestic energy, is estimated at 22 mcm. Thus, the average annual production, within silviculturally permissible limits, is 52 mcm which may reasonably be assumed to be the net annual increment amounting to 1.24% of the total growing stock.

Considering the recorded forest area of the country (75.18 million ha), the average annual production of 52 mcm works out to 0.7 m<sup>3</sup> per ha which is much less than the world average of 2.1 m<sup>3</sup> per ha.

1.3.4 Man-made forests: While the existing naturally regenerated forests of the country continue to provide wood as a raw material, natural regeneration systems are not able to adequately cope with the rising demands of wood because of many limitations. Also, in a large proportion of the forests natural regeneration does not occur at all. This has led to the adoption of artificial regeneration practices, and large areas supporting an inferior natural crop have been replaced by pure and mixed plantations of species of high value. Plantations have so far (up to 1988-89) been raised over an area of 15.365 mha (Table 1.4).

**Table 1.4.** Area afforested (1951-1989) (mha)

Period/Year	Total area afforested	Average annual area afforested
1951-56	0.052	0.0104
1956-61	0.311	0.6222
1961-66	0.583	0.1166
1966-69	0.453	0.1510
1969-74	0.714	0.1428
1974-79	1.221	0.2442
1979-80	0.222	0.2220
1980-85	4.647	0.9294
1985-86	1.510	1.5100
1986-87	1.762	1.7620
1987-88	1.770	1.7700
1988-89	2.120	2.1200
	-----	
Total	15.365	
	-----	

**Source:** GOI (1989a & 1990c)

1.1.3.5 Forest management: Rapid global changes in the field of environment and forest coupled with the ever increasing demands for forest produce call for rational and scientific forest management to increase their productivity. The importance of the social content of forestry must be realised, and involvement of the local communities for sustainable forest management must become an important component of forest management. Emphasis also needs to be put on the multipurpose role of forestry as a tool for ecological stability as well as economic development.

1.1.4 Mangroves, wetlands and biosphere reserves

Mangroves are salt tolerant forest ecosystems found mainly in the tropical and subtropical inter-tidal regions of the world. Under suitable conditions, mangroves may form extensive and productive forests in the sheltered coastlines. Mangroves support numerous terrestrial, arboreal, benthic and aquatic organisms forming a complex association of species, exchanging materials and energy within the system and with the neighbouring coastal waters [Chaudhury, 1989]. Mangroves stabilize the coastal shoreline and protect the landmass from tidal surges, cyclonic storms and high winds. They are important habitat for a range of flora and fauna. According to field surveys, the total mangrove area, regionwise is shown in Table 1.5.

Wetlands are important ecotones or transitional areas between aquatic and terrestrial ecosystems where the water table is usually at or near the surface, or the land is covered by shallow water. They include marshes, swamps, flood-plains, bogs, peatlands, shallow ponds, littoral zones of large water bodies, tidal marshes, etc. Wetlands are important resources as far as crucial role in flood control, nutrient dynamics, recharging of aquifers, regulating water quality and reducing sediment load. They have a high potential for aquaculture and are an important habitat for a wide range of ecospecific wildlife (GOI 1989 b,c). India is rich in wetland resources that exhibit significant ecological diversity, primarily because of the climatic and topographical variability within the country. The regionwise distribution of wetlands is shown in Table 1.5.

**Table 1.5. Regionwise distribution of mangroves and wetlands**

Region	Area (ha)	
	Mangroves	Wetlands
Northern	-	414,936
Western	79,000	1,025,489
Southern	41,000	1,565,307
Eastern	554,000	903,398
North-eastern	-	139,873
All India	674,000	4,050,137

Source: GOI (1987a & 1990d)

A biosphere reserve is an area of terrestrial or coastal environment which is representative of one of the world's natural or biographic regions. The main objective in the establishment of biosphere reserves, is to provide insitu conservation of plants, animals and micro-organisms, not in isolation but in their totality as part of the wider ecosystem (GOI 1989b).

Fifteen mangrove areas and sixteen wetlands have been identified for conservation and scientific management (GOI, 1989b and 1990d). Thirteen potential sites, representing different biogeographical regions in India were identified for setting up of Biosphere Reserves as indicated in Table 1.6.

**Table 1.6. Proposed biosphere reserves in India**

Region	Biosphere Reserves		
	No.	Area (ha)	Sites
Northern	3	594,000	Nanda Devi, Thar Desert, Uttarakh
Western	2	500,000	Kanha, Rann of Kutch
Southern	2	1,602,000	Nilgiri, Gulf of Manas
Eastern	2	137,500	Sunderbans, North Andamans
North-eastern	4	594,000	Namdapha, Kaziranga, Manas, Nokre
All India	13	3,427,500	

Note: Areas of Thar Desert (Northern Region), Kanha (Western Region) and Sunderbans (Eastern Region) are not given in the table they are in the process of demarcation and delineation.

Source: GOI (1987b)



#### 1.1.5 Water resources

Currently, the annual requirement for water is around 600 billion cubic metres (bcm), two-thirds of which is provided by surface waters and the rest by ground water. Annual requirements are expected to reach 750 bcm by the year 2000 and 1050 bcm by the year 2025.

1.1.5.1 Rivers: The river systems of India can be classified into four groups viz. (i) Himalayan rivers, (ii) Deccan rivers, (iii) coastal rivers, and (iv) rivers of the inland drainage basin. The Himalayan rivers are formed by melting of snows and glaciers and, therefore, have continuous flow throughout the year. During the monsoon months, the Himalayas receive very heavy rainfall and rivers swell, causing frequent floods. The Deccan rivers, on the other hand, are rainfed and therefore, fluctuate in volume. Many of these are non-perennial. The coastal streams, specially on the west coast, are short in length and have limited catchment areas. These rivers are of great importance as they contain as much as 14% of the country's water resources while draining only 3% of the land. The streams of inland drainage basin of Western Rajasthan are few and far between. They drain into salt lakes or get lost in sands with no outlet to the sea [Central Water Commission (CWC), 1988].

The annual precipitation is estimated at about 4000 bcm (including snowfall). The seasonal rainfall is of the order of 3000 bcm and the average annual natural flow is estimated to be 1880 bcm (CWC, 1988).

Rivers carry lesser volumes of water during the lean season, which affects irrigation through canals besides shrinking the capacity of the rivers to flush their beds in the plains. Coupled with lesser discharge is the problem of increased withdrawal of waters from the rivers; rivers thereby lose their natural cleansing capacity. With the discharge of industrial effluents and domestic sullage, the quality of water in these rivers has deteriorated so much that the water is unfit for human consumption. As much as 70% of water sources are polluted by human and industrial wastes, most of which can be traced to the discharge of untreated human waste into the natural drainage system. Of the 3119 towns and cities in the country, only 209 have partial and just eight have full sewage treatment facilities (Chaphekar, 1991). Polluted water is responsible for two-thirds of all illnesses and at times the incidence of typhoid, cholera, malaria, diarrhoea, and dysentery reaches epidemic proportions.

Although industrial wastes, discharged into water bodies, are just a quarter of the community wastes, treatment of polluted water is more complex and expensive. This is because of the qualitative differences in pollution according to the industries involved, and due to non-degradability of many of the effluents. Of the over 4000 water-polluting large industrial units, only about half have installed pollution control equipment. Many small units have not even begun to think in terms of controlling pollution.

**Table 1.7. Primary water quality criteria**

Designated Best Use	Class of Water	Criteria
Drinking water source without conventional treatment but after disinfection	A	<ol style="list-style-type: none"> <li>1. Total Coliform Organisms MPN/100ml shall be 50 or less.</li> <li>2. pH between 6.5 and 8.5</li> <li>3. Dissolved Oxygen 6 mg/l or more</li> <li>4. Biochemical Oxygen Demand 5 days 20°C, 2mg/l or less</li> </ol>
Outdoor bathing (Organised)	B	<ol style="list-style-type: none"> <li>1. Total Coliform Organisms MPN/100ml shall be 500 or less.</li> <li>2. pH between 6.5 and 8.5</li> <li>3. Dissolved Oxygen 5mg/l or more</li> <li>4. Biochemical Oxygen Demand 5 days 20°C, 3 mg/l or less</li> </ol>
Drinking water source	C	<ol style="list-style-type: none"> <li>1. Total Coliform Organisms MPN/100ml shall be 5000 or less.</li> <li>2. pH between 6.5 to 8.5</li> <li>3. Dissolved Oxygen 4 mg/l or more</li> <li>4. Biochemical Oxygen Demand 5 days 20°C, 3mg/l or less</li> </ol>
Propagation of wildlife, fisheries	D	<ol style="list-style-type: none"> <li>1. pH between 6.5 and 8.5</li> <li>2. Dissolved Oxygen 4mg/l or more</li> <li>3. Free Ammonia (as N) 1.2 mg/l or less.</li> </ol>
Irrigation, Industrial cooling, Controlled Waste	E	<ol style="list-style-type: none"> <li>1. pH between 6.0 and 8.5</li> <li>2. Electrical Conductivity at 25°C micro mhos/cm Max 2250.</li> <li>3. Sodium Absorption Ratio Max 26.</li> <li>4. Boron, Max 2 mg/l</li> </ol>

Table 1.7 shows the classification of water in terms of designated best use and primary water quality criteria.

Using this classification, Table 1.8 gives an assessment of water quality for the major rivers in India. As can be seen, the most critical parameters are coliforms and Biochemical Oxygen Demand.

**Table 1.8. Water quality of major rivers in India**

River	Length (km)	Level		Critical parameters
		Desired (most places)	Existing	
Baitarani	355	B	Below C	BOD
Brahmani	799	C	Below C	BOD
Brahmaputra	720	C	na	na
Cauvery	800	C	C	-
Ganga	2525	B	na	na
Godavari	1465	B,C	C, below C	BOD
Beas	460	A,C	C, below C	Coliforms, DO
Ravi	370	A,C	C, below C	Coliforms
Sutlej	-	A,C	C, below C	Coliforms, BOD, DO
Krishna	1401	C	C, below C	BOD
Mahanadi	857	C	na	na
Mahi	533	A,C	C, below C	Coliforms, BOD
Narmada	1312	A,B,C	C, below C	Coliforms, BOD
Pennar	597	C	C	BOD
Sabarmati	371	A,E	C, below C	Coliforms
Subarnarekha	395	C	below C	Coliforms, BOD, DO
Tapi	724	A,C	C, below C	Coliforms, BOD
Yamuna	1376	B,C	below C	Coliforms, BOD, DO

- 1.1.5.2 Ground water: There are three important formations of soil and rock in India, which have a bearing on the yield of ground water. A very large portion of the country (nearly 120 mha) consists of consolidated hard rock formation. The yield in such areas is low. In the semi-consolidated formation which covers about 5 mha, sedimentary rocks such as sandstones, limestones and conglomerates occur. The yield in

these area is moderate. These formations occur particularly in Rajasthan, Gujarat and Tamil Nadu. There are large areas of unconsolidated formations consisting mainly of sand, gravel, boulders, laterites, soil and clay. These areas include valleys like Kashmir, the Indus basin, Ganga-Brahmaputra Meghna basin and coastal tracts. These areas yield substantial quantities of ground water.

The Central Ground Water Board (CGWB) has estimated the annual utilisable ground water resources at about 418 bcm while the present annual utilisation is about 100 bcm. This is approximately 24% of the total utilisable resources.

#### **.1.5.3 Effects of deforestation and mining related activities on water resources:**

##### **Deforestation**

Deforestation has very serious impacts on water resources, mainly in the form of increasing soil erosion and water run-off. In India, it is seen in its worst form in watersheds in the Himalaya. It is also manifest in other mountain chains such as the Aravalis, the Vindhya, the Western Ghats and the Eastern Ghats in varying proportions. Roughly about 5300 million tonnes of soil (about 16 tonnes/Ha) is being eroded every year in the country. Soil erosion due to water flow, constant high velocity winds and shifting cultivation, extensively practised in North-East by the tribal population are the major causes of worry. While deforestation in a watershed is a very likely cause of siltation of streams and rivers in that watershed, there is still no conclusive evidence linking this to siltation of rivers far away. In the Himalaya, natural causes of soil erosion far dominate deforestation as a cause. Nearly a tenth of the eroded soil is deposited in reservoirs and this results in the loss of their storage capacity by one or two percent annually. The various multi-purpose reservoirs in the country are silting up fast, and the annual rate of siltation in most of the reservoirs is 146-874% of the figures assumed at the time of construction.

##### **Mining**

As most of the rainfall in India is received in monsoon months, this limits the recharging of ground water. The situation is more serious in mining areas because of poor vegetative cover, steep profiles and thin top soil. The overflows are thus very severe, particularly at the time of high precipitation and it is not uncommon to observe the direct entry of water courses into the mines. This aspect is important in view of difficulties of maintenance of plantations over the reclaimed area. However, during the dry period, the water resources that become available are the

sub-surface run-off in the water courses and the water pumped from the mines. The depleted resources of water influence the area.

#### 1.1.6 Air quality

At the regional level, urban and industrial air pollution is a serious problem in the country. Since most of the growth in population will occur in urban areas, urban air quality will become increasingly crucial to human health. Household pollution, owing to combustion of low grade fuels in traditional devices, in most of the rural areas and in the low income groups of urban areas, is another major concern.

The quality of air can be described meaningfully only with the help of ambient air quality standards. The Central Pollution Control Board (CPCB) laid down the standards in 1982, which are currently being revised. The earlier standards were based on sampling times of 8 hours and monitoring frequency of once a week. The new proposed standards are based on sampling time of 24 hours and monitoring frequency of at least twice a week. Also, the new standards specify that not more than 2% of the total number of observations in a year should exceed the values specified in comparison with 5% in the earlier case. However, more stringent standards by itself will not produce a cleaner environment unless these standards are enforced. The new proposed standards are given in Table 1.9.

**Table 1.9.** Proposed national ambient air quality standards

Pollutant	Averaging Time	Concentration ( $\mu\text{g}/\text{m}^3$ )	
		General Area	Sensitive Area
SO <sub>2</sub>	Annual Avg*	80 (0.03 ppm)	30
	24 h	130 (0.05 ppm)	30
	1 h	655 (0.25 ppm)	
NO <sub>2</sub>	Annual Avg*	100 (0.053 ppm)	30
	24 h	200 (0.106 ppm)	30
	1 h	470 (0.25 ppm)	
TSP	Annual Avg*	200 (400 $\mu\text{g}/\text{m}^3$ )#	100 (200 $\mu\text{g}/\text{m}^3$ )
	24 h	400 (800 $\mu\text{g}/\text{m}^3$ )#	200 (400 $\mu\text{g}/\text{m}^3$ )

\* Annual Arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hourly at uniform intervals.

# Not more than 2% of the total number of observations in a year should exceed the figures presented within the brackets for TSP.

**Source :** Central Pollution Control Board (1991)

Air Quality at specific locations : Based on the data for 33 cities of India, the following findings were made:

- (i) Howrah, Ahmedabad, Annapara and Bhilai have the ten most polluted industrial areas.
- (ii) Surat, Dehra Dun, Delhi, Pune and Bangalore have the ten most polluted commercial areas.
- (iii) Delhi, Kota, Agra, Bhilai, Faridabad have the ten most polluted residential areas.
- (iv) TSP exceeded the standards at almost all the locations.
- (v) Three out of the four locations in Howrah were amongst the top 10 locations that had high concentrations of all the three pollutants. All the three pollutants exceeded the proposed standards.
- (vi) Sulphur dioxide concentrations at all but one location were within the stipulated standards.
- (vii) For nitrogen dioxide, the annual mean values exceeded the proposed air quality standard at Kota and Howrah. The annual mean values for 1989 were higher than the corresponding values for 1988 at almost all the locations at Kota and Madras. Locations in Kota, Howrah, Baroda and Pondicherry violated the 24-hourly averages standard 0-5% of the time.
- (viii) In Howrah, the sulphur dioxide levels exceeded the standards 11-24% of the time.
- (ix) Again, in Howrah and Dehra Dun, TSP levels exceeded the standards more than 75% of the time.
- (x) The nitrogen dioxide standards were exceeded than those most number of times in Kota (15-20%).
- (xi) The mean concentration of TSP in the three classified areas is significantly different, implying thereby that background concentration of TSP in these regions has a significant impact on the measured TSP values.

Clearly, these data suggest that Howrah, Kota, Madras and Baroda have a serious air quality problem. However, very strangely, though Delhi recorded high annual averages, it was absent from the list of the cities where standards were violated for a significant fraction of the time. It is likely that uncertainty in data led to such a result. Data for Bombay have not been collected by CPCB. If we were to consider data gathered by the Municipal Corporation of Greater Bombay, then it is seen that Bombay has the highest levels of nitrogen dioxide in commercial areas. In Table 1.10

we have shown in which regions the above mentioned cities lie.

**Table 1.10.** Cities with high ambient concentrations of air pollutants.

Region	Cities
North	Delhi, Dehra Dun, Kota, Agra, Faridabad
West	Bombay, Ahmedabad, Surat, Pune, Baroda
South	Bangalore, Madras
East	Annapara, Bhilai
North-east	Nil

Comparison with other countries: With regard to SO<sub>2</sub>, the major Indian cities have an average air quality. Countries like China, Brazil, Mexico, Iran, South Korea, France, Italy and Yugoslavia have cities with higher concentrations of SO<sub>2</sub>. But in the context of TSP, Indian cities fare the worst, with Chinese cities having the second highest concentrations (WRI, 1991). Of course, one must keep in mind that background natural dust in semi-arid areas is high. Monitoring of fine particulate matter will resolve this question. The high TSP values may also indicate increasing use of diesel for transport.

### **Energy resources and reserves**

#### **Coal and Lignite**

The quantity of coal reserves available in the country is assessed on a continuous basis regionally by the Geological Survey of India (GSI) through regional mapping and exploratory drilling. Detailed drilling is carried out by other agencies. Since the nationalisation of the coal industry in the early 1970s, the tempo of exploration has increased significantly, and detailed drilling is done by the Central Mine Planning and Design Institute Ltd. (CMPDIL), the Mineral Exploration Corporation (MEC) and the respective State Governments.

Coal is the mainstay of India's energy economy, and is expected to remain so in the foreseeable future. The demand for coal grew at about 8% per annum in the 1980s, and the annual production in 1989/90 crossed the 200 million tonnes (MT) mark.

Total coal reserves are estimated at about 186 billion tonnes (Table 1.11). The major workable deposits of coal occur in a great succession of fresh water sediments, commonly known as "Gondwana" coals of permian age (215 million years ago). These reserves constitute nearly 99.5% of the total coal resources of the country. There are small deposits of coal of tertiary age (25-60 million years ago) in the North-eastern states, which contribute the balance 0.5% of the total resources. In addition, there are lignite deposits of the tertiary age in Tamil Nadu, Gujarat, Rajasthan and Kashmir. Differences in the geological age are accompanied by differences in the chemical composition; the Gondwana coals being largely bituminous, and the tertiary coals largely lignitic and lignite. The bulk of the present economically viable coal reserves is confined to a 14369 sq. km area, distributed amongst 57 peninsular Gondwana coalfields, and 180 sq. km (14 tertiary coalfields) of North-eastern India. Major coal deposits are in Bihar, West Bengal and Orissa (Eastern Region), Madhya Pradesh (Western Region) and Andhra Pradesh (Southern Region).

The salient features of the reserves are as follows:

- (i) reserves under the proven category are only 30% of the total reserves;
- (ii) about 63% of the total reserves occur at depths of 300 metres or less, and 27% occur in the depth range of 300 metres to 600 metres. Only about 10% of the reserves occur beyond 600 metres depth, and are mainly located in deep coal basins like Raniganj, Jharia, South Karanpura, East/West Bokaro and Godavari coalfields;
- (iii) prime coking coal reserves are restricted to Jharia coalfields, and are less than 3% of the total reserves. However, coal deposits that are close to prime coking coal in characteristics have been located in East/West Bokaro and parts of Sohagpur coalfields;
- (iv) reserves of medium coking and semi-coking coals constitute about 13% of the total reserves;
- (v) reserves of superior non-coking coals (grades A, B, and C) are limited (about 12% of total reserves), with the major deposits lying in the Raniganj coalfields. Sizeable reserves are also available in Talcher, Korba, South Karanpura, Chirimiri and a few other coalfields. Substantial reserves of deep-seated superior quality coal have now been identified by regional exploration in Birbhum and Domra-Panagarh areas of West Bengal; and



(vi) the bulk of the coal reserves in the country (73%) are inferior grade non-coking coals, occurring largely in thick interbanded seams and located in coalfields like Singrauli, Ib Valley, Talcher, North Karanpura, Rajmahal, Korba, Wardha and so forth. Recoverable reserves are only 56.5 billion tonnes. Of these, less than 9 billion tonnes are coking coals (prime coking coal reserves being about 1.2 billion tonnes; the rest being medium and semi-coking coals). The remaining 47.5 billion tonnes are non-coking coals - predominantly of an inferior grade. Reserves of grade A and B non-coking coals are less than 1.4 billion tonnes.

Table 1.11 Coal reserves as on 1 January 1990 (billion tonnes)

Type of Coal	Proved	Indicated	Inferred
<u>Coking Coal</u>			
Prime	4.23	1.07	-
Medium	9.37	10.99	1.23
Semi	0.55	0.91	0.62
Sub-total	14.15	12.97	1.85
<u>Non-Coking Coal</u>			
	42.14	68.41	46.52
Total	56.29	81.38	48.37

Source: "Personal Communications", Geological Survey of India, 1

The actual production potential is dependent not on "geological" reserves, but on "mineable" and "recoverable" reserves. according to Government of India (1988c), in which the coal reserves data are analyzed, about 99.2 billion tonnes of mineable reserves are available for future projectisation. A break-up of this estimate of mineable reserves under broad depth and quality classes is given in Table 1.12.

Table 1.12. Mineable and recoverable reserves (billion tonnes)

Type	Depth				Total	
	0-300 m		> 300 m			
	MR*	RR#	MR	RR	MR	RR
<u>Coking Coal</u>						
i) Prime	0.40	0.22	1.90	0.96	2.30	1.18
ii) Medium	6.98	4.01	6.64	3.10	13.62	7.11
iii) Semi	0.38	0.24	0.58	0.37	0.96	0.61
Sub Total	7.76	4.47	9.12	4.43	16.88	8.90
<u>Non-Coking Coal</u>						
i) Superior	10.95	6.76	5.24	2.65	16.19	9.41
a) A & B					2.75	1.38
b) C & D					13.44	8.03
ii) Inferior	47.68	29.87	18.14	8.30	66.09	38.77
Sub Total	58.63	36.63	23.65	10.95	82.28	47.58
	66.39	41.10	32.77	15.38	99.16	56.48

Source: GOI (1988c).

\* MR : Mineable Reserves; # RR : Recoverable Reserves.

The mineable reserves are derived on the following basis:

(i) The certainty equivalent of proven, indicated and inferred reserves (0.9 for proven, 0.65 for indicated and 0.3 for inferred); and (ii) blockage of coal reserves for different geophysical conditions such as underground fires, water, township, railways, roads, etc.

The recoverable reserves based on certain recovery factors for various coalfields and depth-thickness combinations have been worked out by the Planning Commission (1988), and are summarized in Table 1.13. The table shows that 36.6 billion tonnes of non-coking coal and 4.47 billion tonnes of coking coals are mineable from depths of less than 300 metres, using open-cast mining methods.

Compared to coal, lignite reserves are rather small, the proven and inferred reserves together being 8.5 billion tonnes (Table 1.13). Lignite deposits occur mostly in Neyveli (Tamil Nadu in the Southern Region), where the reserves are about 6.55 billion tonnes, of which about 2.1 billion tonnes are proven. These deposits account for about 80% of total proven lignite reserves in the country, and are already being used for power generation in a significant way. Further expansion is in progress. Some smaller lignite deposits in Gujarat are also being developed for power generation.

**Table 1.13. Lignite -- proven and inferred reserves (MT)**

State	Region	Proven	Inferred	Total
Tamil Nadu	South	2100	4450	6550
Pondicherry	South	-	480	480
Rajasthan	North	385	640	1025
Gujarat	West	94	247	341
Jammu & Kashmir	North	7	83	90
All India		2586	5900	8486

#### 1.2.2 Oil and Natural Gas

The total area of sedimentary basins in India is about 1.72 million square km (mkm), of which 1.4 mkm are on land, and the remaining offshore, within the 200 metres isobath line. There are 26 sedimentary basins, of which 13 are of interest geologically. As per the latest estimates available from the GOI's Department of Petroleum and Natural Gas (Personal Communications), the total prognosticated hydrocarbon resources are about 21 billion tonnes of oil and oil equivalent of gas (Table 1.14). Approximately 11.3 billion tonnes are in Category I basins while the rest are in Category II and III basins.\* About 62% of total prognosticated resources are in offshore areas, and over half of total theoretical resources are expected to be in the form of natural gas.

However, as of 1990, the proven and indicated balance recoverable reserves of crude oil and natural gas were only 757 million tonnes and 686 billion cubic metre (bcm) respectively. These reserves are located mainly along the West Coast between the Gulf of Cambay and Bombay and in the North-eastern region in Upper Assam, and may be disaggregated as follows: (i) Bombay High offshore basin: 450 million tonnes of crude oil and 457 bcm of gas; (ii) Cambay basin: 162 million tonnes of crude oil and 93 bcm of natural gas; (iii) Upper Assam basin: 145 million tonnes of crude oil and 135 bcm of gas; and (iv) Rajasthan: 1.04 bcm of gas. A part of the natural gas occurs as associated gas, the production of which is related to oil production.

\* Category I basins: proven petroliferous basins where commercial production has already begun; Category II basins: sedimentary basins with known occurrence of hydrocarbons, but from which no commercial production has yet been obtained; and Category III basins: sedimentary basins in which significant evidence of hydrocarbons has not yet been found, but which, on general geological grounds, are considered possible.

**Table 1.14. Prognosticated hydrocarbon resources**

	Prognosticated Resources (mtoe)	Gas-Oil Ratio (cu.m/t)
<b>Onshore</b>	7772	
Cambay	1650	249.9
Upper Assam	2280	476.3
K. Godavari	217	2796.5
Cauvery	166	835.1
Bengal	326	835.1
Assam-Arakan	2110	820.6
K. Saurashtra	263	835.1
HF & G. Valley	370	835.1
Rajasthan	340	4784.7
Mahanadi	50	835.1
<b>Offshore</b>	12773	
K. Godavari	543	549.8
Cauvery	374	829.1
Bengal	634	1813.5
K. Saurashtra	497	436.9
Kerala-Konkan	1630	2919.2
Mahanadi	1240	1820.3
Andaman	465	1820.3
Bombay High	7390	455.8

**Source:** "Personal Communications", Department of Petroleum and Natural Gas, 1991.

While most of the exploration until 1979 was concentrated in Category I basins, exploration in category II and III basins accelerated substantially in the 1980s. In the Seventh Five-Year Plan period (1985/86 to 1989/90), nearly half of the exploratory effort was in Category II and III basins. This trend of an increasing exploratory effort in category II and III basins is likely to continue over the foreseeable future, as geophysical and surface surveys conducted there so far have shown structures that are favourable for hydrocarbon accumulation. Moreover, as the category I basins have been explored relatively intensively, it is expected that most new discoveries there would be small deposits in stratigraphic traps, which may be difficult to exploit.

Efforts are being made to improve recovery factors from the producing oil fields. The necessary R & D efforts are under-way, and pilot projects using various enhanced oil recovery (EOR) techniques have been initiated. In particular, thermal methods (such as in-situ combustion and steam flooding) and chemical injection methods (such as

polymer/micellar-polymer/caustic flooding) of EOR have been tried. Preliminary results indicate over 10% of additional recovery in all pilot tests.

### 1.2.3 Hydropower

According to available data, India's total economically exploitable hydroelectric potential is 396.4 TWh of annual energy generation, or about 75,400 MW at 60% load factor. Approximately one-fifth of this potential has been developed so far. Most of the unexploited potential is concentrated in the Northern and North-eastern regions (about 48,000 MW). Low demand for electric power impedes development of hydroelectric projects in the Northeast. Over 60% of the potential in the Southern Region has been developed so far.

Hydropower development is now being increasingly integrated into optimal river valley development programmes. Several multi-purpose projects with hydroelectric power as one of the components (the other being surface irrigation) have now been developed. The first such project was in the Cauvery basin at Mettur in the Southern Region.

While the advantages of hydropower are well recognized, the exploitation of hydropower resources has been constrained by several factors. These include differences in inter-state priorities, long gestation periods, financial constraints, and problems of land submergence and resettlement of affected population.

The fact that hydropower development has not kept pace with the demand for power is a cause for concern. Given the Indian energy situation, it is necessary to restore the confidence in hydro development, ensure availability of modern technology for investigation and construction of hydro projects, rationally view the concerns of environmentalists and carefully select some major sites for early development.

One possibility is small hydropower development. No reliable estimates of the potential for small hydro are available. Some idea of the immense potential can be obtained from the estimates made by the Rural Electrification Corporation (REC) based on surveys in the mid 1980s for small hydro power generation potential on existing irrigation systems in the country. Over a thousand sites were identified on existing irrigation dams, canal drops, diversion weirs, etc. and the potential was estimated at over 5,000 MW. The REC survey highlighted the concentration

of projects in the southern states of Andhra Pradesh, Karnataka and Tamil Nadu where the potential was placed at 2000 Gwh of energy annually at 500 sites.

#### 2.4 Nuclear energy

The Department of Atomic Energy estimates the uranium resources to be about 70,000 tonnes, the thermal reactor equivalent of about 1.9 billion tonnes of coal. India also has thorium deposits, estimated at 360,000 tonnes, that can support a large nuclear programme based on breeder reactor technology. Thorium is seen as the single most important energy resource in the long term.

#### 2.5 Biomass fuels

Unlike commercial energy sources, biofuels are by-products of livestock, agricultural and forestry resources which play different primary roles in the economy. These fuels make a significant contribution in meeting energy demands in the domestic sector.

2.5.1 Fuelwood: The current production of fuelwood from forests, as estimated by the Forest Survey of India, is placed at 52 million m<sup>3</sup> (36 million tonnes) [GOI, 1989a]. This includes the unrecorded production of fuelwood in the form of dead/dying and seasonally fallen wood which is collected from the forests as head-loads by the villagers living near the forests. This, however, is on the lower side of estimated sustainable yields which vary between 36-43 MT/year. The optimistic regionwise sustainable firewood yield is summarised in Table 1.15. The estimates from the so called "unrecorded sources" which include supply of fuelwood from private lands, gardens, trees around houses, shifting cultivation areas and the like show even a higher level of disparity. These estimates are in the range of 30-80 MT/year [GOI (1989a) and Advisory Board on Energy (1985)]. Thus, the total availability of fuelwood, at present is in the range of 66-123 MT/year including both recorded and unrecorded sources.

**Table 1.15. Regional biomass availability (1989) (MT)**

Region	Sustainable firewood yield	Non-fodder crop residues	Dung fuel (wet)
East	5.555	18.514	82.754
North	4.948	49.662	99.020
North-East	12.109	3.004	0.003
South	7.590	37.393	13.577
West	12.334	32.476	49.244
<b>Total</b>	<b>42.536</b>	<b>141.049</b>	<b>244.598</b>

No significant increase is expected in the supply of fuelwood in the coming decade from forest areas, as the resource base is shrinking due to a population increase and other developmental activities. Additionally, green felling from forests has been stopped in many states on environmental considerations. The supply of fuelwood from forests would, therefore, remain static at the present levels, if it does not decrease. The availability from non-forest sources beyond AD 2000 would essentially depend on the social forestry and afforestation work undertaken in the next decade.

1.2.5.2 Crop residues: Crop residues are those plant materials that are left in the field or in agro-based industries after extracting the main crop produce. These materials are available in the form of straws, stalks, husk, leaves, fibrous material, roots and other parts of the plant material. No reliable data are available with regard to the quantity of crop residues used either as fodder or fuel. A rough estimate for non-fodder crop residues for the year 1989 is around 140 MT/year, out of which 65-70 MT/year is already in use in the sugar industry. Regionwise estimates are given in Table 1.15.

1.2.5.3 Dung-cakes: It is estimated that the total dung fuel available for 1989 was about 245 MT (wet basis). It is expected that the bovine population will not increase beyond the 1990 estimates without affecting its quality. Therefore, dung production is expected to stabilise in the future. Regionwise details are shown in Table 1.15.

#### 1.2.6 Wind energy

A recent exercise on wind mapping and wind monitoring of potential regions in India has identified several locations along the western/southern coasts and inland areas where wind power generation would be economical. Some sites identified in Tamil Nadu are comparable with the best windfarm sites in

the world. The potential for wind power generation on the basis of land availability, wind speeds, and economic viability have been computed to be more than 150000 MW. However, the peak generating capacity of conventional units and the availability of the grid are some of the limiting factors and the technically realisable potential has been estimated to be 40000 MW.

#### .7 Solar energy

Radiation climatology of the Indian subcontinent is fairly well documented. Computed radiation data at scales useful for analysing solar energy utilisation indicate that the country as a whole receives about 2000 kWh/m<sup>2</sup>/year with the highest amount in western India and the lowest in the east and north east (about 1700 kWh/m<sup>2</sup>/year). Solar energy can be used for low grade thermal applications (solar cooking, hot water systems, etc.) as well as for high temperature applications such as solar thermal power generation.

#### .8 Energy trade options in the Indian subcontinent

The two main energy trade options are electricity (hydropower) and natural gas.

.8.1 Hydropower: Nepal and Bhutan have large hydropower potential estimated at 83,000 MW and 20,000 MW respectively, with an exploitable potential of 44,500 MW and 20,000 MW respectively. At present, Nepal has an installed capacity of 232 MW and Bhutan 355 MW, 95% of which is currently utilised by India. Major schemes being studied between India and Nepal include Karnali (3,000-6,000 MW) and Pancheswar (2,000-3,000 MW). For the Karnali project, in accordance with a common understanding with India, the latest feasibility study has been carried out which proposes an installed power capacity of 10,800 MW to be used as a peaking station with a capacity factor of 20%.

.8.2 Natural gas: In recent years, it has been proposed that Bangladesh export natural gas to India. However, this appears unlikely in the near future. According to the document of the Fourth Five Year Plan for Bangladesh, gas reserves in 1990 stood at 13 tcf of which 1.35 tcf had already been utilized. The plan forecast a gas consumption growth rate of 9.8% for the period 1990-95. If this rate were to continue and no new reserves were added, depletion levels will be reached around the year 2005. Recent estimates, however, put reserves at a much higher level of 25 tcf. However, at the same time,



demand is being forecast at higher rates as well (15% p.a.) and depletion levels are expected to be reached by 2010. Given these scenarios gas exports seem unlikely.

There is another area where cooperation between India and Bangladesh could help solve energy problems. Tripura, a state in India's North-east, has large gas reserves which are largely unutilized at present. Transporting this gas to consumption centres in eastern India poses a major infrastructural problem. If this gas is transported through a pipeline that lies wholly inside Indian territory, it will not only have to cover a long distance but will also have to pass through extremely difficult terrain. If, however, Bangladesh were to allow India to transport the Tripura gas through a pipeline which cuts across its territory, the costs would fall substantially, making the supply of gas to the eastern region of India economically feasible.

A unique and ambitious proposal of piping natural gas from Iran through Pakistan to India was mooted at an international conference held in New Delhi in 1990. Such an effort would require unprecedented cooperation amongst India and Pakistan. This pipeline would have obvious benefits for these two countries; in addition, since it is proposed to extend the pipeline deep into South India, possibilities for supplying Sri Lanka also open up.

The location of the gas reserves is in the vicinity of Bandar Abbas in the Persian Gulf. The gas processing is designed to process a total of 50 mcmd of gas and the estimated length of the pipeline is 3,000 km.

More details on this section can be found in Jaitly and Suri (1992).

## CHAPTER 2

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### Energy demand

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#### 1 Trends in energy demand

India is highly dependent on fossil fuels for meeting its commercial energy requirements. It has moved from being largely a biomass based economy at the time of independence to a 60 per cent dependence on commercial energy forms. Coal and petroleum products form the main energy sources although the share of natural gas is increasing quite rapidly.

A broad sectoral analysis of energy demand reveals that the fastest growing sectors, in terms of energy consumption, are the agricultural and the residential sectors wherein consumption has grown at 11.42 per cent and 9.36 per cent respectively during the period 1972-73 to 1988-89 (Table 2.1). In terms of absolute energy consumption, the industrial sector accounts for a major part followed by the transport sector. Utilization of various energy forms for non-energy purposes (naphtha as feedstock, lubes and greases and natural gas used in industry) has also increased rapidly, at about 7 per cent per annum, during the same time period.

An analysis of energy demand by fuel reveals that the share of industry in total electricity consumption has declined considerably over the period 1980-81 to 1988-89 while that of the agricultural and residential sectors has increased quite significantly. While residential electricity demands have gone up from 11 per cent to 14 per cent of total electricity demands, the issue of significance here is that, these demands are found to coincide with the peak demand. In case of the agricultural sector the increase in demand is largely due to the Government policy of rural electrification and thereby energisation of pump-sets. The state electricity boards, however, adopt a number of measures to ensure that rural pump-sets do not operate during periods of system peak demand.

Table 2.1. Trends in availability and consumption of commercial energy : 1972-73 to 1988-89  
(million tonnes of oil equivalent)

Year	Gross availability	Conversion losses	Net availability/consumption (col4-9)	Agriculture	Industry	Transport	Residential	Other energy uses	Non energy uses
1972-73	68.483	14.396	54.087 (100.0)	0.78 (1.4)	29.717 (54.9)	13.579 (25.1)	4.533 (8.4)	1.542 (2.9)	3.936 (7.3)
1980-81	92.623	23.859	68.764 (100.0)	1.625 (2.3)	36.861 (53.6)	17.443 (25.4)	5.637 (8.2)	1.901 (2.8)	5.297 (7.7)
1982-83	109.023	28.552	80.471 (100.0)	1.861 (2.3)	44.225 (55.0)	18.758 (23.3)	6.82 (8.5)	2.127 (2.6)	6.68 (8.3)
1984-85	121.51	34.997	86.513 (100.0)	2.131 (2.5)	46.595 (53.8)	20.309 (23.5)	8.038 (9.3)	2.341 (2.7)	7.099 (8.5)
1986-87	141.187	40.927	100.26 (100.0)	2.807 (2.8)	53.423 (53.3)	22.789 (22.7)	9.532 (9.5)	2.677 (2.7)	9.032 (9.0)
1988-89	163.606	52.621	110.985 (100.0)	3.861 (3.5)	56.214 (50.6)	26.055 (23.5)	11.532 (10.4)	3.684 (3.3)	9.639 (8.7)

Source : Compiled from energy balances in TERI, 1990.

Note : Figures in brackets give percentage shares.

The share of the transport sector in oil consumption has been increasing due to the absence of an alternative transportation fuel both in the road sector as well as in railways. Electrification of rail routes is limited by the density of traffic required to make this an economically viable option. Similarly, in the domestic sector the only commercial energy alternative to cooking fuels is petroleum based products. Both these factors have contributed to the disproportionately large demand for middle distillates (kerosene and diesel) in India.

In 1990-91, close to 61 per cent of coal consumption was accounted for by the power sector and 35 per cent by the industrial sector. Coal consumption by railways is declining due to a conscious policy adopted by the Government of India to phase out the highly inefficient steam locomotion and replace them with diesel and electric traction.

Natural gas consumption in the country is still extremely low with well over 30 per cent of natural gas produced being flared in 1989-90. Industry accounts for close to 98 per cent of the gas that is consumed, largely in fertilizer and petrochemicals industries (non-energy purposes) and for power generation.

Given the past growth and pattern of energy demand the present study attempts to provide snapshot pictures of future energy demands. To do so energy demands have been disaggregated regionally and projected into the future using an end-use approach. Sectoral growths are first estimated and then useful energy consumption norms applied to them.

Next, these useful energy demands are distributed over alternative fuels taking into account efficiencies of utilization, availability of various fuel types and population distribution patterns. Demands have been based on two scenarios, the definitions of which are given below.

Scenario I:

- (i) GDP grows at an average real rate of 5 per cent per annum.
- (ii) The population growth rates estimated by the Standing Committee of Experts on the Population Projections (Planning Commission), October 1988 are used with some modifications. Population grows at an annual rate of growth of 2.01 per cent up to the year 1999-2000 and 1.81 per cent thereafter till 2009-10. By extrapolation of past trends the share of northern region in total population increases from 28.7 per cent in 1991 to 30.4 per cent in 2009-10, while those of southern and western regions decline from 23.3 per cent and 22.2 per cent to 21.8 per cent and 21.7 per cent respectively over the same time period. Shares of the eastern and north eastern regions remain unchanged.
- (iii) Urbanization at the national level increases from 27.5 per cent in 1991 to 37.5 per cent in 2009-10. This trend is estimated on the basis of projections made by the Planning Commission (GOI, October 1985).
- (iv) In the agriculture sector, the output grows at an annual rate of growth of 3 per cent. This is in consonance with the Planning Commission projections up to the year 2000.
- (v) For industry, the following growth rates have been assumed: textiles: 4 per cent, electrical machinery: 11.8 per cent, non-electrical machinery: 12.5 per cent, chemicals and petrochemicals: 9 per cent, iron and steel (mini plants): 11.79 per cent, aluminium: 7.7 per cent, cement: 7.3 per cent, paper: 4 per cent and fertilizer: 5.7 per cent. These growth rates are obtained either from the 7th Five Year Plan document or based on the opinion of experts in these areas. The iron and steel production is projected on the basis of project-wise capacities under construction up to the year 2004-05 (Centre for Monitoring the Indian Economy, 1989) and extrapolated to the year 2009-10 at an annual rate of growth of 2.9 per cent, the estimated average rate of growth projected for the period 1999-2000 and 2004-05.

- (vi) In the transport sector, the rail:road mix (in percent) changes from 20.22:79.78 in 1988-89 to 13.3:86.7 in 2009-10 in case of passenger transport and from 47.8:52.2 to 35.3:64.7 over the same time frame in case of freight transport. The Steering Committee on Perspective Planning for Transport Development, Planning Commission has worked out these shares for 1987-88 and projected them for the year 2000. For analytical purposes, the rail-road mix in 1989-90 and 1994-95 is worked out by linear interpolation while in 2004-05 and 2009-10 these are assumed to be at 2000 level. In general, the share of roadways increases at the expense of rail transportation.

Within railways, the share of coal engines declines exponentially and becomes negligible by the year 2004-05, while the shares of both electric and diesel traction increase at varying rates in different regions of the country based on past trends. In case of road transportation, the shares of different modes are an average of the observed shares during the period 1980-81 to 1984-85; buses account for more than 80 per cent in total passenger transportation and trucks (both LCVs and HCVs) account for over 97 per cent of total freight transportation.

- (vii) In the urban residential sector, by fitting a log-normal curve, the income distribution of population changes in such a manner that there is a decrease in the percentage of population in the lowest income bracket. Large sections of population graduate into higher income brackets thus leading to about 25 per cent of population in the the highest bracket in 2009-10 as against a mere 9.5 per cent in 1990-91 (refer to section 1.1 in Annexure for details).
- (viii) The estimates of energy demand for the rural domestic sector is based on a normative thermal energy demand of 520 Kcal per capita daily (and this is assumed to be constant in the period of the projection time horizon). The fuel mix used in the estimates (and the projections) are based on the state-wise estimates indicated by the domestic fuel survey of NCAER in 1979.

There is very little evidence of a correlation between energy consumption and income, even if it could be established that the benefits of economic growth percolate to rural areas. As a result of this, the volume effects (changes in the energy

demand due to the expansion the economy) of the energy demand estimates and projection just include historical growth of the population. Lack of information on the structural changes and the likely impacts of such changes precludes its inclusion in the demand projection for this sector. The effect of efficiency changes have been partial addressed in the section on greater use of renewables (biogas and improved cookstoves).

Scenario II:

- (i) The real rate of growth of GDP is 6 per cent per annum.
- (ii) Annual rate of increase of population declines from 1.81 per cent in the period 1990-91 to 1994-95 to 1.42 per cent during 2004-05 to 2009-10. The rates of growth during the period 1990-91 to 2004-05 are as given by the Standing Committee of Experts on Population Projections (Planning Commission, 1988) and extrapolated linearly up to the year 2009-10. The regional shares continue to be the same as in Scenario I.
- (iii) Level of urbanization remains the same as in Scenario I.
- (iv) In the agriculture sector, as against Scenario I, the output of 3-5 per cent per annum.
- (v) For industry, in consultation with the Planning Commission, the following growth rates are assumed- textiles: 7.8 per cent, electrical machinery: 10 per cent, non-electrical machinery: 8.4 per cent, chemicals and petrochemicals: 8.8 per cent, iron and steel (mini plants): 11.79 per cent, aluminium: 7.5 per cent, cement: 9.6 per cent, paper: 7.2 per cent and fertilizer: 8.3 per cent. The iron and steel production from integrated plants is projected in a way similar to Scenario I.
- (vi) In the transport sector, the rail:road mix and the modal shares remain the same as in Scenario I. However, total transportation demand changes as a result of population changes and increased industrial production.
- (vii) In the urban residential sector, distribution of population improves at a rate faster than in Scenario I, because the higher rate of growth of GDP combined with lower population growth results in a higher per capita urban income. The share of population in the lowest income bracket decreases from 8.7 per cent in 1990-91 to 2.5 per cent in 2009-10 while that in the

highest bracket increases from 9.5 per cent to about 26 per cent over the same period.

- (viii) As indicated in (viii) of Scenario I, the impact of higher economic growth will be negligible for the rural domestic sector energy demand.

## **2.2 Methodology for sectoral energy demand projections**

### **2.2.1 Agriculture**

Energy consumption in the agricultural sector increased rapidly over the period 1971-88. The agricultural sector has been under tremendous pressure to increase productivity not only due to an increasing population in rural areas, but also due to an increasing non-agricultural based population.

Land area available for agricultural purposes has been more or less stagnant from the early 1970s. However, there has been an increase in gross cropped area due to the increased intensity of land use through double cropping and multiple-cropping. A large part of this increase in gross cropped area has been possible due to the introduction of energy intensive high yielding varieties (HYV) of crops since the late 1960s which have a high energy input intensity. The introduction of the HYVs and the high incidence of droughts since the mid-1960s have contributed to the increased use of energy in the agricultural sector.

Although the estimates of diesel consumption in agriculture are not well recorded, the information on electricity consumption is well documented. The increasing consumption of electricity has resulted from the decision taken by several State Governments to have flat tariffs based on the horse-power rating of agricultural pump-sets. Little information is available on the end-use for which electricity is being demanded.

Two agricultural operations known to be energy intensive, land preparation and irrigation, were taken up for projecting agricultural energy demands. This involved the projection of area, production and yields for the principal foodgrain and non-foodgrain crops by region and estimating the energy requirements for irrigation and land preparation. Greater details are provided in section 1.2.1 of the Annexure.

Four major energy intensive foodgrain crops, namely rice, maize, wheat and gram, were considered. A semi-log time trend was projected on the 5-year moving average of total foodgrain production to remove the impact of unforeseen and/or random occurrences. The production level in 2009-10 implied an average annual growth rate of 3 per cent over the period 1988-89. A simple time trend was fitted on the 5-year moving averages of yields for each crop (region-wise) to

project yields till the year 2009-10. The gross cropped area was estimated by dividing the production estimates by projected yields.

The non-foodgrain crops covered were groundnut, rapeseed, and mustard - which together account for 80 per cent of the production and 55 per cent of the area under oilseeds - and cotton and sugarcane.

2.2.1.1 Irrigation: Energy demand for irrigation is dependent largely on the quantity of water required and the height over which it has to be lifted. The water requirement for each crop which is irrigated was estimated as the product of the gross cropped area, water requirement per unit of area, fraction of area irrigated from underground sources and finally a scale factor to take into account the relative increase in gross irrigated area as against gross cropped area. This was done primarily to account for future increases in irrigation demand which would be essential to bring about increases in yield and cropping intensity.

Groundwater requirement was estimated using the following equation.

$$U_{it} = \sum_c [GCA_{ict} \times W_c \times PI_{ic} \times PU_i \times E_t] \dots (Eq.2.1)$$

where,

$U_{it}$  = the groundwater requirement in region i at time t (cubic meters)  
 $GCA_{ict}$  = gross cropped area under crop c in region i at time t (hectares)  
 $W_c$  = water requirement for crop c (cubic meters/ha)  
 $PI_{ic}$  = percent of irrigated area in region i for crop c  
 $PU_i$  = percent share of underground sources in region i  
 $E_t$  = index for change in area irrigated  
 $i$  = north, south, west, east and north-east regions  
 $c$  = rice, maize, wheat, gram, groundnut, rapeseed and mustard, cotton and sugarcane.

Once the total water required from underground sources was worked out, it was assumed that the bulk of energy demand (about 3/4ths) would be met by using electric pump-sets. Diesel pump-sets are, by and large, used as a stand-by and brought into operation only if electricity is not available in the quality and quantity desired (TERI, 1990a). Thus, diesel was assumed to meet only 1/4th of total energy demand for irrigation.

It has been assumed that the average head over which water needs to be pumped is 20 metres in case of the 5 per cent GDP growth scenario and 25 metres in case of the GDP growth scenario of 6 per cent. The standard formula for estimating energy requirements E (in kcal) used is given below.



$$E = \frac{Q \times h \times t \times 860}{102 \times n_p \times n_m \times n_t} \dots\dots (Eq.2.2)$$

where

Q - rate of discharge (in litres/second)  
h - head over which the water has to be lifted (in metres)  
t - time (in hours)  
 $n_p$  - pump efficiency  
 $n_m$  - motor efficiency  
 $n_t$  - transmission and frictional losses.

An overall system efficiency of 32.4 per cent was assumed (Karnataka Energy Consultants).

2.2.1.2 Soil preparation: The trend in the stock of tractors per unit of gross cultivated area was observed over the period 1966 to 1987 for each region and the projected up to 2009-10. The product of gross sown area and projected figure of tractors per unit area gave the tractor population.

The average usage of tractors for land preparation and other agricultural operations was taken at 252.3 hours per annum (TERI, 1991). The average horsepower rating of tractors which varies from 15 HP to 35 HP was taken as 30 HP (Mittal et al., 1985). The fuel consumption by tractors was taken as 0.125 litres/HP (Mittal et al., 1985) or 3.75 litres per hour.

The estimates of tractor population, HP rating, annual usage and fuel consumption norms were used to arrive at diesel consumed by tractors for land preparation and other

agricultural activities besides transportation. The formula used for this purpose is given below.

$$DLP_t = \sum_i [TP_{it} \times F \times H] \dots\dots (Eq.2.3)$$

where  $DLP_t$  - diesel used for land preparation at time t  
F - fuel consumption per hour (litres/hours)  
H - hours of usage (annual)  
 $TP_{it}$  - tractor population in region i at time t

## 2.2.2 Industrial sector

The industrial sector, in particular the manufacturing sector, accounts for a major part of the energy consumption in India. The manufacturing sector contributes about 21 per cent of the gross domestic product in the Indian economy but consumes more than half of the total commercial energy. In percentage terms, this sector accounts for 45.5 per cent of the total electricity consumption and also for a large part of the demand for specific petroleum products as brought out in Table 2.2.

**Table 2.2.** Share of industrial sector in  
overall fuel consumption  
(per cent)

Fuel	Share of industries in total fuel consumption	Share of major industries in industrial fuel consumption
Coal	95.57	25.68
Electricity	45.49	67.00
HSD	7.90	51.37
LDO	66.00	55.13
FO	83.00	79.03
LSHS	98.80	86.16

Source : [TERI, Jan-Mar 1991]  
[GOI, Various issues (Ref.No. 3,5,6)]

Within the manufacturing sector eight major industries account for nearly 70 per cent of total industrial energy consumption. These industries are : (1) Iron and steel (2) Aluminium (3) Paper (4) Fertilizer (5) Cement (6) Textiles (7) Engineering industries (electrical and non-electrical) (8) Chemicals and petrochemicals. Shares of different type of fuels consumed by these eight industries are also shown above in Table 2.2.

For projecting energy demands it was decided to restrict the analysis to the above-mentioned eight industries. After obtaining the energy demands of individual industries, the overall energy demand of the industrial sector was estimated by assuming that the share of these eight industries in total industrial energy consumption will remain more or less at the present level.

In case of industries which produce a homogeneous product, the output was measured in physical units whereas in case of industries which produce heterogeneous products the output was measured in terms of monetary values (value added at 1980-81 constant prices).

State-wise time series data on production for cement, aluminium, fertilizer, paper and iron and steel industries as well as value added in the textiles, engineering, chemicals and petrochemical industries were compiled. These were aggregated to arrive at regional outputs of each of the industries. The estimates of output/value added at the regional level were projected for different terminal years using the growth rate obtained from Planning Commission or on

the basis of the expert opinions pertaining to the 5 per cent and 6 per cent rate of growth of GDP. Having projected outputs or value added, specific energy consumption norms and observed fuel shares were used to compute energy consumption in each of the industries. While detailed methodology is given in section 1.2.2 of the Annexure.

The regional consumption of each fuel aggregated over all the eight industries at the end of each terminal years was estimated by using the following formula.

$$F_{rpt} = \sum_i [X_{irt} \times e_{ip} \times (1 - c_{it})]$$

where,

$F_{rpt}$  = consumption of the fuel p in region r at the end of time period t

$X_{irt}$  = output/value added of  $i^{th}$  industry in  $r^{th}$  region at the end of the  $t^{th}$  year ( $i = 1,8$ ), ( $t = 1,4$ )

$e_{ip}$  = consumption of  $p^{th}$  fuel in the  $i^{th}$  industry per unit of output/value added

$c_{it}$  = energy conservation potential in the  $i^{th}$  industry in time period t

Since this represented the fuel demand from the eight major industries only, these values were appropriately scaled up based on the current percentage share of the fuel consumed in the eight industries to the total consumption by all industries.

### 2.2.3 Transport sector

The transport sector in India is a major energy (especially oil) consuming sector. Of the total public sector investment on transport, more than 75 per cent is allocated to the development of rail and road transportation systems, with less than 25 per cent being invested in other sub-sectors viz. shipping, inland water transport, air transport etc.

Inadequate investments have led to a decline in the share of railways in total passenger traffic from nearly 62.2 per cent in 1950-51 to as low as 19.8 per cent in 1984-85. In case of freight traffic, the share of railways declined from a high level of 78.5 per cent in 1950-51 to 41.5 per cent in 1984-85. Road transport makes up for a large part of the balance transportation demand.

In the present analysis, the forecasts of demand for passenger movement [in passenger kilometers (pkm)] have been arrived at by relating it to the levels of population and that for freight movement [in tonne kilometers (tkm)] by relating it to the regional domestic product levels. These were apportioned between movement by road and rail on the basis of the projected shares of each. Subsequently, on the

basis of past data, the total traffic demand was further classified by modes of transport such as electric, diesel and steam traction in railways and buses, trucks, cars/taxis, etc. in road transport such as under the broad categories of railways and roadways. Finally, the demand for energy was projected by taking into account the total volume of traffic, both passenger and freight, handled by each mode and its intensity of energy consumption. The details of the methodology are presented in section 1.2.3 in the Annexure volume of this report.

Following equations were used in estimating the demand,

$$\log (\text{TPKMSPc}) = 2.336 + (0.024 \times t)$$

where,

TPKMSPc = total passenger kilometers per capita

t = time variable i.e. 1 for 1960-61, 2 for 1961-62 and so on.

$$\text{TKM} = -88.94 + 0.0033 \text{ GDPfc}$$

where,

TKM = total tonne kilometers of freight (BTKM)

GDPfc = gross domestic product at factor cost in 1980-81 prices (Rs.crores).

The rail-road mix given by the Steering Committee on Perspective Planning for Transport Department (GOI, 1988b) for the base year 1986-87 and for the year 2000 were used for interpolating the mix for each of the intermittent years i.e. 1989-90 and 1994-95. The shares of rail and road in the years 2004-05 and 2009-10 were assumed to remain the same as in 1999-2000.

Within railways, the share of coal-driven engines was assumed to decline exponentially over time and this becomes negligible or gets phased out completely by the year 2004-05. This is in consonance with the government policy in this respect. Subsequently, the residual shares were ascribed to electric and diesel traction on a proportional basis for each of the years under consideration.

The shares of different modes in road transportation in future were taken as an average of the observed shares in the five years from 1980-81 to 1984-85 (ENCON, 1986).

As far as the passenger movement by bus is concerned, a distinction was made between the volume of inter-regional and intra-regional traffic. The Steering committee [GOI, 1988] states the share of the two to be 16.5 and 83.5 per cent respectively in 1986-87. In the absence of additional information, similar shares were assumed to be applicable in the future years also.

The quantum of energy consumed in both passenger and freight traffic by rail and road was estimated by taking into account the volume of traffic handled by the alternative modes and the fuel intensity of each. The intensity of fuel consumption in railways was obtained from the report of the National Transport Policy Committee [GOI, 1980]. These are given in Tables 1(Annexure).35 and 1(Annexure).40.

The techno-economic parameters, such as carrying capacity and specific fuel consumption specified in Tables 1(Annexure).36 and 1(Annexure).41 were assumed for different vehicles in road passenger and freight transport. The fuel consumption norms for different modes in 2009-10 were taken as those for the most efficient vehicle on the road today with a linear interpolation of values for the intermittent years.

#### 2.2.4 Urban residential sector

It was observed that population distribution for 1987-88 derived from the consumer expenditure survey carried out by the National Sample Survey Organisation (42nd Round) closely follows a log-normal distribution. Future distributions were estimated by fitting a log-normal distribution and specifying three basic parameters namely, the poverty line, proportion of population below it and average monthly per capita expenditure in urban areas in each of the years under consideration (for details see section 1.1 of the Annexure). The distributions were worked out for the two scenarios namely, (i) high population with 5 per cent annual growth of GDP and (ii) low population with 6 per cent annual growth of GDP (greater details are provided in section 2.1 of this chapter). The expenditure distribution was converted to income distribution by using rate of savings in each income category.

The urban residential sector in India is an important consumer of commercial energy. There are large rural-urban and regional differences in the composition of fuels which are consumed in this sector. The consumption of biofuels such as charcoal, dung, crop residues, firewood etc. is largely confined to rural India while modern fuels such as electricity, LPG, kerosene and soft coke are largely used in the urban areas. These differences in the mix of fuels consumed in rural and urban areas are clearly brought out in Table 2.3.

**Table 2.3. Rural-urban differences in energy consumption**

Fuel	Monthly consumption per capita	
	Rural	Urban
<b>Commercial</b>		
Soft coke (kg)	0.19	2.61
Kerosene (l)	0.43	0.97
LPG (kg)	-	0.18
Electricity (kWh)	0.41	2.92
<b>Biomass fuels (kg)</b>		
Firewood	13.17	9.73
Vegetable waste	4.92	0.67
Dungcake	11.80	3.00
Charcoal	-	0.30

**Source:** Dharmarajan (1988).

Energy consumption in households is closely related to the income level of the households. At lower levels of income, the use of energy is mainly restricted to meeting the basic needs such as cooking. As incomes rise, the share of other end-uses such as space cooling and heating, water heating and refrigeration etc., rise rapidly. Furthermore, an increase in the level of household incomes is accompanied by a switch from non-commercial to more convenient, modern and commercial sources of energy, namely kerosene and LPG.

A normative approach was adopted to estimate the consumption of different fuels in the urban domestic sector (TERI, 1988). Since the actual consumption norms are estimated on a per capita basis, the urban population, classified by income-class and region, was used to work out the total consumption of the fuel in different years. The energy demands were estimated separately for the two scenarios mentioned above.

Annual energy demand for the  $p^{\text{th}}$  fuel was computed by using the following formula:

$$C_p = \sum_{jr} [E_{pjr} \times U_{pjr} \times P_{jr}]$$

where,

$$\begin{aligned} C_p &= \text{annual consumption of fuel } p \text{ (kg or kwh)} \\ E_{pjr} &= \text{per capita consumption of } p^{\text{th}} \text{ fuel in } j^{\text{th}} \text{ income class and } r^{\text{th}} \text{ region (kg or kwh)} \\ U_{pjr} &= \text{percentage of user population of } p^{\text{th}} \text{ fuel in } j^{\text{th}} \text{ income class and } r^{\text{th}} \text{ region} \end{aligned}$$

$P_{ij}$  = population in  $j^{th}$  income class and  $r^{th}$  region (million)  
 $p$  = fuels such as LPG, kerosene, soft coke, dung, firewood, electricity  
 $j$  = income class  
 $r$  = regions namely north, south, west, east and north-east

#### 2.2.5 Rural residential sector

Biomass remains the major source of cooking energy in the rural areas in India (NCAER 1985). The end-use planning approach has been used to estimate the energy requirements for cooking and lighting in this sector.

The actual cooking energy requirements would depend on common food items cooked in the household. This, in turn, would largely be determined by the cropping pattern in a subsistence rural economy based on agriculture. In order to roughly estimate the energy requirements for cooking, National Sample Survey data on consumption of foodgrains was used (NSSO, 1986).

Estimates of the useful thermal energy requirements for achieving cooking tasks were then used to compute the total useful energy requirements for the cereals consumed. It must be emphasised that the data on energy requirements for cooking different food items are limited. Therefore, the estimates made in Table 2.4 are approximate for this reason.

Table 2.4 Estimates of useful energy requirement for cereal preparation among expenditure classes

		Energy requirement for cooking				
		Monthly expenditure class (in Rs)				All classes
		lowest	middle	highest		
	in kJ/kg    kcal/kg	(0-10)	(50-60)	(> 200)		
Rice	3000    717	16	183	237		170
Wheat	3400    812	4	101	281		110
Jowar	3000    717	3	41	27		42
Bajra	3400    812	0	21	36		20
Maize	3500    836	2	18	18		19
Barley	2700    645	0	5	7		5
Small millets	2500    597	0	4	2		4
Ragi	3000    717	2	12	9		12
Total		26	385	617		381

Given a requirement of 380 kcal/capita/day for cooking cereals, the energy requirement norm of 520 kcal per person per day assumed in several studies seems to be acceptable.

Hardly any attention has been devoted to the question of the fuel mix for meeting energy demand for rural areas. Of the issues involving demand estimates for rural areas and thereafter estimating the demand for different fuels (especially biofuels), the fuel mix issue is probably the most complex. The most recent data on state-wise fuel mix are those presented in the NCAER survey of 1978/79 (NCAER 1985). The analysis here uses this information for computing fuelwise consumption in the domestic sector. Other estimates used for this study are as follows (Table 2.5).

**Table 2.5.** Normative energy requirement:  
520 kcal

	Calorific value	Efficiency (per cent)
Fuelwood	4700	12
Crop residues	4200	10
Dung cake	3000	12

#### Thermal energy requirements

As for biofuels, the methodology followed for projecting the demand for kerosene in the domestic sector of rural areas of India has been somewhat ad hoc in the past. The GOI (1965) norms of 29 litres/household/year were revised to a marginally higher figure of 29.76 litres/household/year (GOI, 1979). The 32nd round of the National Sample Survey (NSS) estimated the national average consumption in the rural areas at 37.62 litres/household/year while the NCAER (1985) estimated the national average consumption at 30.05 litres/households/year.

#### Summary results

5 per cent GDP growth scenario: The sectoral energy demands that have been estimated in the previous sections have been aggregated and corrected for the likely consumption by commercial and other sectors to arrive at total energy demands. The kerosene consumption for lighting purposes is assumed to be accounting for 60 per cent of total kerosene consumption in rural areas.



Table 2.6. Demand projections for electricity (GWh)

	North	West	South	East	N East	All-India
<b>1989-90</b>						
Industry	14808 41	32872.89	25077.18	16887.83	957.80	90604.11
Transport	1463.03	1054.92	1015.41	1102.91	296.80	4933.08
Domestic	10250 00	11060.00	7820.00	4050.00	650.00	33840.00
Agriculture	21974 70	7484.09	9413.52	6404.29	25.46	45302.06
Others	5388.00	5830 00	4814 00	3161.00	214.00	19409.00
TOTAL	53885 00	58302.00	48140 00	31606 00	2145.00	194088 00
<b>1994-95</b>						
Industry	21381.13	47806.74	36137 33	20975 43	1829 66	128130
Transport	1803 55	1319.87	1208 61	1336 61	409 21	6077 85
Domestic	15872 91	13848 54	11258.91	5454.38	939 98	47374 73
Agriculture	43231.00	18802 00	16400 00	13684 00	58.00	92175 00
Others	9143 00	9086 00	7223 00	4606 00	360 00	30418 00
TOTAL	91431 00	90863 00	72228 00	46056 00	3597 00	304175.00
<b>1999-2000</b>						
Industry	29918 30	65622 92	51302 51	26136 29	2384.95	175365 00
Transport	2107 11	1434 78	1309 77	1481 09	468.01	6800 77
Domestic	20940 62	15895 90	13954 56	6843 42	1183.80	58818 30
Agriculture	48272.00	21464.00	19143 00	16262 00	70.00	105211 00
Others	11249 00	11602 00	9523 00	5636 00	456 00	38466 00
TOTAL	112487.00	116019 00	95233 00	56358 00	4563 00	384661 00
<b>2004-05</b>						
Industry	43632 12	93370 25	72712 30	34810 50	3222 73	247748 00
Transport	2973 33	1998 37	1752 36	2023 99	673 25	9421 29
Domestic	28003.85	18105 75	17286 94	8490 07	1558.53	73445 14
Agriculture	54139 00	24540 00	22365.00	19259 00	83.00	120387 00
Others	14305 00	15335 00	12680 00	7176 00	615 00	50111 00
TOTAL	143054 00	153349.00	126796 00	71760 00	6153 00	501113.00
<b>2009-10</b>						
Industry	64885.22	134712	106791	48545.36	4435.42 <sup>p</sup>	359369.00
Transport	4175.46	2772.06	2337 71	2750.72	962.10	12998.05
Domestic	37503.36	22742 50	21656.57	10920.77	2122.83	94946.03
Agriculture	60926.00	28095.00	26157.00	22744.00	99.00	138021.00
Others	18610.00	20925.00	17438.00	9440.00	847.00	67259.00
TOTAL	186100.00	209247.00	174379.00	94401.00	8466.00	672593.00

Table 2.7. Demand projections for coal (million tonnes)

	North	West	South	East	N East	All-India
1989-90						
Industry	6.38	21.02	18.43	29.27	0.23	75.34
Power	28.09	40.22	19.86	25.93	0.89	115.00
Transport	1.74	0.80	0.72	1.41	0.48	5.15
Domestic	0.57	0.64	0.03	0.27	0.04	1.56
Others	0.34	1.11	0.97	1.54	0.01	3.97
TOTAL	37.11	63.79	40.01	58.42	1.66	201.01
1994-95						
Industry	10.39	32.75	27.49	37.38	0.90	108.91
Power	41.18	58.97	29.12	38.02	1.31	168.61
Transport	1.83	0.62	0.50	1.17	0.39	4.51
Domestic	0.69	0.84	0.04	0.35	0.05	1.98
Others	6.01	10.35	6.35	8.55	0.30	31.56
TOTAL	60.09	103.53	63.50	85.47	2.95	315.56
1999-2000						
Industry	12.19	37.02	34.99	38.11	0.86	123.18
Power	55.58	74.10	40.33	50.83	1.31	222.15
Transport	1.69	0.40	0.31	0.88	0.33	3.60
Domestic	0.86	1.01	0.05	0.44	0.07	2.43
Others	7.81	12.50	8.41	10.03	0.29	39.04
TOTAL	78.14	125.03	84.09	100.29	2.85	390.41
2004-05						
Industry	16.21	47.15	41.50	42.31	0.95	148.11
Power	74.50	89.89	55.68	65.31	1.31	286.70
Transport	1.90	0.34	0.24	0.82	0.36	3.67
Domestic	0.98	1.23	0.07	0.51	0.08	2.87
Others	10.40	15.40	10.83	12.11	0.30	49.04
TOTAL	104.00	154.00	108.31	121.05	3.01	490.39
2009-10						
Industry	21.68	59.35	53.35	49.40	1.09	184.87
Power	104.56	115.00	80.08	88.33	1.31	389.29
Transport	2.15	0.29	0.18	0.78	0.41	3.81
Domestic	1.11	1.47	0.08	0.57	0.10	3.33
Others	14.39	19.57	14.85	15.45	0.32	64.59
TOTAL	143.89	195.68	148.55	154.53	3.23	645.89

Strangely enough, while electricity demand over the last twenty years has grown at an average annual rate of 8 per cent and coal and oil demands at 5.6 per cent and 5.8 per cent respectively, over the next twenty years the growth in

demand for all the above three energy forms has settled around 6 per cent. This could be due to a variety of factors such as conservation, more efficient energy use in agriculture, technology/process change in industry etc. However, natural gas consumption increases at nearly 9 per cent annually.

In terms of percentage shares, it is seen that the industrial sector's consumption of electricity has increased consumption from the present level of approximately 47 per cent to over 53 per cent in 2009-10. Shares of the domestic and agricultural sectors have declined to 14 per cent and 21 per cent from 17.5 per cent and 23 per cent respectively. The All-India peak demand is seen to increase from a level of 42,000 MW in 1989-90 to 115,000 MW in 2009-10. The growth in peak demand is lower than that of electricity due to the increasing share of the industrial sector which has a much smoother load profile vis-a-vis the domestic sector.

No major changes are seen in the case of coal consumption, with industry and power continuing to account for close to 90 per cent of total coal consumption. However, the share of the power sector has increased from about 57 per cent to 60 per cent at the cost of industrial coal consumption. While the transport sector still consumes nearly 4 million tonnes of coal, in percentage terms its share is almost negligible at 0.5 per cent. An interesting thing to note is that the share of Western region in total coal consumption has declined while that of the Northern and Southern regions has increased. The share of the Eastern region wherein most of the coal is found is also seen to be declining probably due to relatively lower level of developments as compared to the other regions.

The transport sector continues to account for a large part of total oil demand (51 per cent) up to the year 2009-10. The other major consumer is the industrial sector whose share has decreased to about 19 per cent of total oil consumption (24 per cent including power). The share of the domestic sector (12.42 per cent) in this scenario is seen to be declining largely due to the assumption that the per capita kerosene consumption in rural areas would remain at present levels. Thus, kerosene consumption in rural areas is increasing only at the rate of growth of the population. The share of agriculture in oil consumption works out to about 5.5 per cent.

Natural gas consumption would increase at a rate of 9 per cent per annum over the period 1989-90 to 2009-10. The power sector would account for close to 62 per cent of this demand, the balance being made up by industry. Significantly, the share of the North-Eastern sector in

natural gas consumption has increased to about 16 per cent from a level of well below 10 per cent today. The share of the Western and the Southern regions has increased while that of the North has declined.

Table 2.8. Demand projections for oil ('000 tonnes)

	North	South	West	East	N East	All-Ind
1989-90						
Industry	1284.00	1490.00	3660.00	822.00	87.00	13194.0
Power	637.25	450.58	912.45	588.39	20.34	2609.0
Transport	3897.63	4242.17	4253.02	3644.36	645.43	18457.6
Domestic	2145.99	2830.98	3434.87	1626.67	462.70	10499.0
Agriculture	2791.78	794.56	1014.50	617.93	19.23	5238.0
Others	154.99	201.25	529.29	116.27	12.74	1014.5
Total	10911.64	10009.40	13803.95	7415.98	1247.38	51011.6
1994-95						
Industry	2985.00	3185.00	7203.00	1884.00	264.00	15522.0
Power	926.60	655.17	1326.76	855.56	29.57	3793.6
Transport	11095.29	7920.76	8434.75	6709.44	1074.57	37444.8
Domestic	2777.41	3534.64	4116.75	1984.85	532.68	12943.8
Agriculture	3075.69	875.37	1117.67	680.77	21.18	5770.6
Others	1211.26	1020.97	1634.11	703.03	91.51	4660.8
Total	22071.42	17192.08	23833.20	12818.08	2013.41	80135.6
1999-00						
Industry	3602.00	4081.00	8936.00	2398.00	309.00	19326.0
Power	1250.51	907.43	1667.16	1143.64	29.57	4998.3
Transport	16215.36	10833.35	11609.06	9352.01	1516.88	52246.6
Domestic	3414.32	4066.92	4701.87	2370.00	613.01	15163.6
Agriculture	3605.58	1056.29	1330.48	824.32	27.95	6844.6
Others	1640.16	1367.12	2168.06	945.61	124.26	6245.2
Total	29727.50	22311.74	30412.96	17033.39	2621.00	104824
2004-05						
Industry	4535.00	5342.00	11534.00	3238.00	377.00	25026.0
Power	1676.19	1252.84	2022.60	1469.53	29.57	6450.7
Transport	21839.53	13858.29	15018.02	12185.21	2011.96	68273.0
Domestic	4209.58	4755.69	5552.23	2898.45	729.77	18145.7
Agriculture	4219.69	1275.18	1579.58	992.07	36.15	8102.6
Others	2175.88	1807.95	2910.76	1272.14	165.56	8332.2
Total	38655.54	28291.90	38617.42	22055.85	3349.75	13433
2009-10						
Industry	6029.00	7344.00	15408.00	4525.00	479.00	33785.0
Power	2352.69	1801.79	2587.49	1987.44	29.57	8758.9
Transport	29415.93	17778.18	19467.57	15931.55	2678.29	89381.5
Domestic	5196.22	5580.09	6528.85	3499.72	867.88	21675.2
Agriculture	4932.45	1540.93	1871.96	1187.98	46.07	9579.4
Others	2924.61	2436.34	3959.10	1734.17	222.24	11276.4
Total	50851.26	36481.06	49823.00	28865.72	4323.19	174456.

Table 2.9. Demand projections for natural gas (BAU-low scenario)

	North	South	West	East	N East	All-India
1989-90						
Industry	1552.45	942.06	2942.37	303.11	130.00	5870.00
Power	1282.48	352.58	1229.89	75.02	440.03	3380.00
Total	2834.93	1294.64	4172.26	378.13	570.04	9250.00
1994-95						
Industry	1708.08	1036.50	3237.33	333.50	143.04	6458.45
Power	6400.58	1759.66	6138.11	374.40	2196.12	16868.86
Total	8108.66	2796.16	9375.44	707.90	2339.16	23327.31
1999-00						
Industry	2685.02	2002.64	5308.95	531.70	250.97	10779.29
Power	8830.20	2701.56	9773.68	374.40	4288.79	25968.63
Total	11515.22	4704.20	15082.63	906.10	4539.76	36747.92
2004-05						
Industry	3917.32	2995.68	7873.59	764.99	377.22	15928.80
Power	9421.35	3273.00	11547.13	374.40	6259.29	30875.17
Total	13338.67	6268.68	19420.72	1139.39	6636.51	46803.97
2009-10						
Industry	5691.51	4624.02	11959.38	1070.57	578.21	23923.70
Power	10360.84	4181.17	14365.58	374.40	9390.90	38672.88
Total	16052.35	8805.19	26324.96	1444.97	9969.11	62596.58

The above analysis shows the changing mix of energy sources with the South increasing its share of both coal and gas consumption and thereby electricity consumption as well and the West reducing its dependence on coal while making increasing use of gas. The Eastern region exhibits declining shares in the consumption of almost all energy sources.

Demand projections for biomass fuels are given in Table 2.10.

6 per cent GDP growth scenario : The optimistic growth scenario considers a 6 per cent growth in GDP accompanied by a lower rate of growth of population than that assumed in the earlier scenario. Although part of the energy demand increases as a result of higher growth of GDP is offset by lower population growth, in the aggregate there is a significant increase in energy consumption levels.

**Table 2.10.** Projection of regional consumption of fuels in domestic sector of rural areas (BAU scenario)

	1990- 1991	1994- 1995	1999- 2000	2004- 2005	2009- 2010
<b>Firewood (mt/y)</b>					
North	21.37	23.14	25.04	27.06	29.21
West	36.29	38.87	45.57	44.36	47.24
South	34.72	36.35	37.99	39.63	41.26
East	19.27	20.83	22.50	24.30	26.23
North-east	6.66	7.26	7.92	8.62	9.37
<b>TOTAL</b>	<b>118.30</b>	<b>126.45</b>	<b>135.01</b>	<b>143.97</b>	<b>153.31</b>
<b>Agricultural waste (Air dry) (mt/y)</b>					
North	13.69	14.79	15.95	17.20	18.5
West	5.82	6.26	6.72	7.20	7.6
South	11.88	12.41	12.94	13.48	14.0
East	20.74	22.65	24.73	26.99	29.4
North-east	3.19	3.48	3.79	4.13	4.4
<b>TOTAL</b>	<b>55.33</b>	<b>59.59</b>	<b>64.14</b>	<b>68.99</b>	<b>74.1</b>
<b>Animal waste (Air dry) (mt/y)</b>					
North	28.27	30.60	33.09	35.74	38.5
West	21.23	22.81	24.47	22.20	27.9
South	4.44	4.65	4.87	5.08	5.2
East	24.72	26.79	29.03	31.43	34.0
North-east	Neg.	Neg.	Neg.	Neg.	Neg
<b>TOTAL</b>	<b>78.67</b>	<b>84.86</b>	<b>91.45</b>	<b>98.44</b>	<b>105.8</b>
<b>Kerosene (mt/y)</b>					
North	0.732	0.791	0.854	0.922	0.99
West	0.796	0.854	0.914	0.976	1.04
South	0.684	0.716	0.747	0.779	0.81
East	0.742	0.805	0.874	0.947	1.02
North-east	0.133	0.145	0.158	0.172	0.18
<b>TOTAL</b>	<b>3.09</b>	<b>3.31</b>	<b>3.55</b>	<b>3.80</b>	<b>4.06</b>

**Table 2.11. Energy demand growth under an optimistic scenario  
(6 per cent growth in GDP & a low population growth)**

	North	West	South	East	N East	All India
<b>1994-95</b>						
Electricity	106966.00	98421.00	78055.00	50216.00	3244.00	336903.00
Coal	60.60	105.90	65.50	85.60	2.00	320.80
Oil	22885.66	24829.87	17723.35	13104.78	2064.38	83035.54
Natural gas	8545.50	9772.90	2893.20	746.30	2583.70	24542.60
<b>1999-00</b>						
Electricity	133865.00	126205.00	102693.00	61552.00	4322.00	428637.00
Coal	82.90	134.30	92.30	102.80	2.00	414.30
Oil	31558.05	32401.54	23481.14	17684.72	2748.11	111131.10
Natural gas	12569.80	15828.30	4779.40	1059.20	5019.80	39256.40
<b>2004-05</b>						
Electricity	169435.00	168537.00	135224.00	77894.00	6078.00	557168.00
Coal	117.30	173.30	126.50	129.20	2.30	548.60
Oil	41730.30	41649.55	38891.72	22956.01	3549.69	153086.00
Natural gas	15112.90	20767.70	6488.10	1481.80	7526.80	51377.20
<b>2009-10</b>						
Electricity	211163.00	226621.00	180548.00	99877.00	9357.00	727566.00
Coal	171.60	234.20	186.10	173.20	2.80	768.90
Oil	55256.89	53804.99	38597.35	29749.76	4575.43	187637.90
Natural gas	18949.50	28367.80	9110.40	2092.70	11699.50	70219.80

As is to be expected, growth in demand for individual energy products over the base year 1989-90 is higher than in the earlier scenario with a 6.5 per cent, 6.9 per cent, 6.4 per cent and 9.5 per cent increase in demand for electricity, coal, oil and natural gas respectively. In comparing the energy consumption levels in 2009-10 over the two scenarios, it is seen that while electricity consumption in the latter scenario is higher by 8 per cent, coal consumption is higher by 19 per cent, oil by 7.5 per cent and natural gas by 12 per cent. These variations are due to a different structural mix that has been assumed for the 6 per cent GDP growth scenario.

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**Energy supply projections**

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**3.1 Introduction**

The supplies of major conventional, commercial energy sources like coal, hydrocarbons and electricity in the past decade or more have been normally constrained by availability of resources\*. This fact and detailed energy supply expansion programmes consistent with the BAU development strategy have been taken into account while projecting energy supply and likely penetration of renewable energy forms to the year 2010 under the low and high growth scenarios. In other words, relationships between GDP and planned/actual investment in the energy supply subsectors have been extrapolated using GDP growth rates of 5% and 6%. This approach however, could not be used for renewable energy technologies, which have accounted for only 0.1% to 1.2% of annual investment levels in the energy sector during the 1980s and for which, the investment levels are anticipated to increase relatively rapidly in the coming decades.

However, this approach enables us to modify to reasonable levels, the rather ambitious targets for energy supply expansion, as given in various reports# prepared for providing inputs into the Eighth Five Year Plan framework. The methodology adopted for a fuelwise regional supply projection and the results are detailed below.

**3.2 Coal**

The share of coal produced from open-cast mining (using both the shovel-dumper and drag-line techniques) has increased steadily since the mid-1970s, and reached a level of about 64% in 1989/90. This trend is anticipated to continue, and the share of coal from open-cast mines is expected to rise to 67% by 1994/95, 70% by 1999/2000 and 73% by 2004/05. This

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\* Financial resources in the public sector, which influence investment levels in various economic sectors in each five-year planning period.

# Referred to as "Working Group" reports for coal, power etc.



share is assumed to stabilize at 73% after 2004/05, largely because of the poor quality of coal produced by adopting this technology -- free dirt, boulders and other lumpy extraneous matter also get mined along with coal.

Available data from 1980/81 through 1988/89 show that on the average, investment in the coal mining industry accounted for 0.47% of GDP. Maintaining this level of investment in the future, the total investment in the coal industry is projected to increase from about \$1.1 billion (1990/91 prices) in 1990/91 to \$2.75 billion (1990/91 prices) in 2009/10, i.e. at the rate of about 5% per annum. Table 3.1 gives the projected levels of investment in the coal industry to the year 2009/10.

Available data also show that the investment required to create 1 million tonne per annum (mtpa) mining capacity is different for open-cast and underground mines. Open-cast mines, which are mechanized, entail an average investment cost of \$74.7 million/mtpa capacity. Mechanized underground mines require about \$100.3 million/mtpa capacity. However, not all new underground mines commissioned in recent years have been fully mechanized -- the non-mechanized ones are less capital intensive. As a result the average capital expenditure incurred on underground mines in the past three years has been \$66.9 million/mtpa. It is assumed that the average level of mechanization of underground mines will increase gradually (as the productivity, measured in tonnes of coal output per man-shift, is higher than in non-mechanized mines) to reach full mechanization by the year 2004/05. Moreover, owing to the rapid increases in costs of mining equipment, the real term investment requirements per mtpa of mining capacity are further expected to escalate by 2% per annum.

**Table 3.1.** Coal -- Investment projections

(\$ million, 1990/91 prices)

Year	Investment projection	Year	Investment projection
1989/90	1036.6	2000/01	1772.9
1990/91	1088.4	2001/02	1861.6
1991/92	1142.8	2002/03	1954.7
1992/93	1200.0	2003/04	2052.4
1993/94	1260.0	2004/05	2155.0
1994/95	1323.0	2005/06	2262.8
1995/96	1389.1	2006/07	2375.9
1996/97	1458.6	2007/08	2494.7
1997/98	1531.5	2008/09	2619.4
1998/99	1608.1	2009/10	2750.4
1999/00	1688.5		

On this basis fairly rapid increases in coal production have been projected -- from about 209 million tonnes (MT) in 1988/89 to 573 MT in 2009/10 -- an average growth rate at the rate of 5.2% per annum. The all-India production of coal has been further divided over the regions on the basis of the percentage share of total coal reserves in each region. These are further split between coking and non-coking coal production on the basis of the share of coking and non-coking coal reserves in each region. The results are presented in Table 3.2.

**Table 3.2. Coal -- Regional break-up of production of coking and non-coking coals (MT)**

UC/OG	CC/MCC	1989/90	1994/95	1999/00	2004/05	2009/10
WR	Total	75.16	86.71	99.17	113.99	125.87
OC	CC	0.90	1.18	1.47	1.78	2.01
OC	NCC	54.09	70.92	88.44	106.85	120.61
UG	CC	2.50	1.81	1.15	0.66	0.40
UG	NCC	17.67	12.80	8.11	4.69	2.85
SR	Total	17.80	36.76	42.37	47.33	47.84
OC	CC	-	-	-	-	-
OC	NCC	7.54	23.36	29.44	35.95	37.51
UG	CC	-	-	-	-	-
UG	NCC	10.26	13.41	12.93	11.38	10.33
ER	Total	102.45	157.96	223.84	301.18	395.88
OC	CC	16.64	25.63	37.55	53.29	70.65
OC	NCC	43.40	66.84	97.90	138.95	184.22
UG	CC	20.66	31.90	43.06	53.07	68.69
UG	NCC	21.75	33.59	45.34	55.88	72.32
NER	Total	1.20	3.04	4.34	3.93	3.70
OC	CC	-	-	-	-	-
OC	NCC	0.84	2.67	4.01	3.68	3.50
UG	CC	-	-	-	-	-
UG	NCC	0.36	0.38	0.33	0.25	0.20
All India						
OC	CC	17.54	26.82	39.02	55.07	72.66
OC	NCC	105.87	163.79	219.78	285.43	345.84
UG	CC	23.16	33.71	44.20	53.73	69.09
UG	NCC	50.04	60.18	66.71	72.20	85.70
Total		196.61	284.48	369.71	466.44	573.29

Note: NER-North-eastern Region; ER-Eastern Region; WR-Western Region;  
 SR-Southern Region; OC-Opencast; UG-Underground;  
 CC-Coking Coal; MCC-Non Coking Coal;

All non-coking coals produced from open-cast mines are of inferior grade (referred to as INCC or inferior non-coking coals), and those produced from underground mines are of superior grade (referred to as SNCC or superior non-coking coals). INCC include "E", "F" and "G" grade coals\*; while SNCC will generally be of "A", "B", "C" and "D" grades\*\*.

Table 3.2 shows that total coal production (CC or coking coals plus INCC plus SNCC) is concentrated in the Eastern Region. While in 1989/90, the Eastern Region accounted for 49.1% of total coal production in the country, this share will increase gradually to 69.1% by 2009/10. The rate of increase of coal production in the Eastern Region is 7% per annum from 1989/90 to 2009/10, compared to 5.2% for the entire country. Although total coking coal production is projected to increase to over 140 MT by 2009/10, a major portion of this will comprise poor quality medium and semi/weakly coking coals -- which would be more suitable for use as industrial/utility boiler fuel.

It is assumed that lignite production, as a percentage of total coal production, will remain the same as in recent years (after 1985/86), i.e. at 5.7%. Further, as bulk of the lignite reserves are in the Southern Region (Tamil Nadu), a large share of lignite production will remain there. Table 3.3 summarizes the region-wise projections of lignite production. In the Southern Region, the lignite production is projected to increase to 34.51 MT in 2009/10; and in the Western and Northern Regions to 2.18 MT each.

According to experts from GOIs Department of Coal, it may not be possible, for geological reasons, to sustain an annual coal production level of beyond 550 to 600 million tonnes. Therefore, even in the 6% per annum GDP growth case, the coal production levels may not change significantly from the 5% GDP growth scenario.

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- \* "E" grade: ash plus moisture content (AMC) of 32 to 35%;  
useful heat value (UHV) of 3360-4200 kCal/kg;  
median gross calorific value (MGCV) of 4700 kCal/kg;
  - "F" grade: AMC above 35%; UHV = 2400 - 3600 kCal/kg;  
MGCV = 4000 kCal/kg;
  - "G" grade: AMC above 35%; UHV = 1300 - 2400 kCal/kg;  
MGCV = 3300 kCal/kg.
  - \*\* "A" grade: AMC less than 17%; UHV above 6200 kCal/kg;  
MGCV = 6300 kCal/kg;
  - "B" grade: AMC of 17-19%; UHV = 5600 - 6200 kCal/kg;  
MGCV = 6100 kCal/kg;
  - "C" grade: AMC of 19-24% UHV = 4940 - 5600 kCal/kg;  
MGCV = 5700 kCal/kg;
  - "D" grade: AMC of 24-32%; UHV = 4200 - 4940 kCal/kg;  
MGCV = 5200 kCal/kg.

**Table 3.3. Lignite -- Regional break-up of production (MT)**

Region	1989/90	1994/95	1999/00	2004/05	2009/10
NR	0	0	0.56	1.27	2.18
WR	1.33	1.86	1.96	2.07	2.18
SR	10.53	14.75	19.96	26.43	34.51
Total	11.86	16.61	22.48	29.77	38.86

### Hydrocarbons

Although the development of the indigenous oil industry has received a high priority since the mid-1970s, only about 25% of the prognosticated hydrocarbon resources have been proven so far. As the exploratory effort is in the initial stages in several basins, geological information required for making reasonable projections on the success of exploratory activity may not be available even with the oil industry. Therefore, the approach adopted is to use normative data for different basins on average gas-oil ratios (GOR), expected discovery index (EDI), indicative costs per metre for exploratory and development drilling and so forth (Table 3.4).

**Table 3.4. Hydrocarbons - Petroliferous basin particulars**

	Prognosticated Resources (mtoe)	R/P Ratio	Total Dev. Drilling Cost (\$/metre)	(1990-91 prices)		
				Expected discovery index (Tonnes/metre)	Direct Exploratory Drilling Cost (\$/metre)	Gas-Oil Ratio (cu.m./tonne)
Onshore	7772					
Cambay	1650	10	606.5	188	310.3	249.9
Upper Assam	2280	13	703.6	750	646.7	476.3
K. Godavari	217	15	927.9	286	1443.2	2796.5
Cauvery	166	15	606.5	273	1443.2	835.1
Bengal	326	15	1037.2	215	1186.7	835.1
Assam-Arakan	2110	15	1037.2	335	999.2	820.6
K. Saurashtra	263	15	606.5	257	310.3	835.1
HF & G. Valley	370	15	1037.2	260	999.2	835.1
Rajasthan	340	15	606.5	220	1140.5	4784.7
Mahanadi	50	15	1037.2	215	507.1	835.1
Offshore	12773					
K. Godavari	543	15	2573.6	1374	2760.9	549.8
Cauvery	374	15	2399.1	643	2760.9	829.1
Bengal	634	15	2573.6	843	2760.9	1813.5
K. Saurashtra	497	15	2573.6	832	2760.9	436.9
Kerala-Konkan	1630	15	2181.1	696	2760.9	2919.2
Mahanadi	1240	15	2573.6	843	2760.9	1820.3
Andaman	465	15	2573.6	910	2760.9	1820.3
Bombay High	7390	15	2181.0	1701	2221.4	655.8

Source: GOI (1988) and Ministry of Petroleum and Natural Gas.

Indicative values of direct exploratory drilling costs per metre for each basin are obtained from GOI (1988). Direct drilling costs account for 58% of total exploratory drilling costs in onshore areas, and 32% in offshore areas [GOI (1989)]. Assuming that exploratory drilling in 2009/10 is in line with present estimates of resource prognostications, it is estimated that the overall average cost of exploratory metre drilled in the year 2009/10 will be \$5081.8 (1990/91 prices). Total investments in exploration are first projected to 2009/10, along with drilling costs per metre in onshore and offshore areas. Available data on total investment in hydrocarbon subsector in the 1980s, and projected investment levels as per GOI (1989) indicate that about 0.57% of GDP is earmarked for exploration activity -- which is used as a basis for projecting investments for exploration work (Table 3.5). As total investment in exploration in 2009/10 is projected at \$3396.4 million, the total exploratory metreage drilled will be 668,350 metres. Given the exploratory drilling in various basins in 1988/89, the metreage is interpolated basin-wise\*.

The basin-wise EDI is then used to compute the annual reserve additions; the prognosticated resources of free gas are treated separately from oil/associated gas reserves. About 25% of the oil and associated gas reserves and 65% of the free gas reserves are assumed to be recoverable. To compute the yearly hydrocarbon production levels basin-wise, an iterative procedure is adopted, keeping in view that: (i) the reserves to production (R/P) ratio of oil and associated gas in each basin at the end of 2009/10 should remain at the levels given in Table 3.4; and (ii) commercial production from a basin begins five years after the first exploratory well is drilled. Further, as the potential to produce free gas is high (about 85% of all possible gas production will be free gas), it is assumed that its production will be curtailed so that total gas production equals gas demand, and flaring becomes negligible.

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\*It is assumed that the exploratory drilling begins in 1990/91 in the Kutch-Saurashtra (onshore and offshore) basins, and in 1995/96 in the Kerala-Konkan (offshore), Andaman (offshore) and Mahanadi (onshore and offshore) basins.

**Table 3.5. Hydrocarbons - Projections of investment levels**  
(\$ million, 1990/91 prices)

	Exploration	Production/Development
1990/91	1344.1	727.3
1994/95	1633.7	884.0
1999/00	2085.1	1128.3
2004/05	2661.2	1440.0
2009/10	3396.4	1837.8

Total oil and associated gas outputs and free gas production potentials are aggregated region-wise. Table 3.6 presents projected levels of oil and associated plus free gas production potentials. Oil production increases from 30.63 mtoe in 1990/91 to 70.49 mtoe in 2009/10, at the rate of 4.48% p.a.; gas production potential increases faster from 18.10 billion cubic metres (bcm) to 68.27 bcm, at the annual average growth rate of 7.24%.

**Table 3.6. Hydrocarbons -- Projections of Oil and Gas production**

		1990-91	1994-95	1999-00	2004-05	2009-1
<b>A. Oil production (MT)</b>						
<b>Onshore</b>	NR	0.00	0.00	0.00	0.04	0.39
	NER	5.35	6.11	7.34	9.11	11.90
	ER	0.00	0.00	0.00	0.03	0.26
	WR	4.77	5.03	5.38	5.75	6.19
	SR	0.12	0.17	0.26	0.42	0.79
<b>Offshore</b>	ER	0.00	0.00	0.00	0.04	1.00
	WR	20.24	23.97	29.62	36.60	45.66
	SR	0.15	0.28	0.59	1.34	4.31
<b>Total</b>		<b>30.63</b>	<b>35.55</b>	<b>43.19</b>	<b>53.32</b>	<b>70.49</b>
<b>B. Gas production potential (bcm)</b>						
<b>Onshore</b>	NR	0.00	0.00	0.02	0.22	2.27
	NER	3.60	4.65	7.24	9.98	12.25
	ER	0.00	0.00	0.01	0.05	0.41
	WR	1.57	1.84	2.47	2.78	2.66
	SR	0.15	0.24	0.51	1.12	3.04
<b>Offshore</b>	ER	0.00	0.00	0.01	0.22	4.55
	WR	12.66	16.67	25.86	33.69	36.69
	SR	0.12	0.24	0.64	1.58	6.40
<b>Total</b>		<b>18.10</b>	<b>23.63</b>	<b>36.75</b>	<b>49.64</b>	<b>68.27</b>

To estimate investments for oil field development activity, the investment in capital equipment required at oil field sites (oil/gas gathering stations, gas-oil/water oil separators etc.) is limited to developmental drilling costs. This is done basin-wise and the results are given in Table 3.5. It is estimated that development drilling nearly doubles from less than 0.6 million metres in 1990/91 to about 1.1 million metres in 2009/10.

While refining capacity will also increase in absolute terms, its share is assumed to decrease from about 92% of total demand for refined products in 1989/90 to below 75% in 1994/95 and remain at that level to the year 2009/10. As per present expectations, the refining capacity by March 1995 will increase to 61.815 million tonnes per annum (mtpa) which implies that refining capacity will meet about 73% of product demand in the low GDP growth scenario. Capacity utilization is assumed at 90% and losses at 6% of the crude throughput. For every 6 mtpa of refining capacity that is added, 1 mtpa of fluidized catalytic cracker (FCC) and 1 mtpa of hydro-cracker (HC) capacity will also be added.\* Investments in refineries are estimated at US\$ 1116 million, US\$ 1844 million, US\$ 2207 million and US\$ 3089 million during the four successive five-year intervals from April 1990 to March 2010; capacity is assumed to increase from 49.85 mtpa in March 1990 to 138.38 mtpa in March 2000.

Normative capital investment data on natural gas pipelines, obtained from the Gas Authority of India Ltd (GAIL) are : (i) for new pipelines on land, about \$75.0 per standard cubic metre per day (SCMD) of gas throughput capacity; (ii) for expansion of throughput of existing pipelines on land, \$54.9/SCMD; and (iii) for construction of pipelines offshore (including requisite gas processing facilities etc.), \$71.3/SCMD. Along with the estimates of increased gas production and demand, investment on pipelines are computed and presented in Table 3.7. It may be noted that investment in onland gas pipelines is related to demand for gas; while for offshore pipelines, to production of gas from offshore areas.

If the GDP were to grow at 6% per annum, the investment levels for hydrocarbon exploration and production would increase, leading to a higher output. In particular, the

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\* It is assumed that minor light distillates will account for 2.65% of total production of light distillates, minor middle distillates for 1.2% of all middle distillates, and minor heavy ends for 22.5% of all heavy ends.

**Table 3.7. Investment in natural gas pipelines**  
(\$ million, 1990/91 prices)

	1990/91 to 1994/95	1995/96 to 1999/00	2000/01 to 2004/05	2005/06 to 2009/10
Onland	2164	2389	1790	2811
Offshore	1294	740	1002	2530
Total	3458	3129	2792	5341

investment for exploration and production/development activities would increase to \$4139 million and \$ 22422 million respectively by 2009/10. The production of oil would increase to 86.02 MT, and of associated plus free gas to a maximum of 75.89 bcm. Refining capacity increase is assumed to remain the same as in the low GDP growth scenario, as a substantial expansion of India's refining capability is evident even in the low growth case. Investment on natural gas pipelines will be \$3.8 billion, \$3.6 billion, \$3.5 billion and \$6.7 billion in four successive five-year intervals from 1990/91 to 2009/10.

## Power

The power supply industry in India is one of the fastest growing subsectors. The organized Indian power supply industry has accounted for 16% to 18% of total public sector investments since the mid-1970s, and 2.2% to 2.5% of GDP in the 1980s. Such high dependence on planned budgetary resources may not be sustained during the twenty year time-frame to 2010, but significant private sector investment is expected. It is estimated that about 25150 MW of new capacity will be added between April 1990 and March 1995, about 29750 MW from April 1995 to March 2000, 34480 MW from April 2000 to March 2005, and 51770 MW from April 2005 to March 2010\*. Table 3.8 gives the detailed break-up region-

\* According to GOI (1989), about 38000 MW of capacity will come on-stream by March 1995. However, as some projects will get delayed, it is assumed that all sanctioned/ongoing projects and some Central Electricity Authority (CEA) cleared projects will be commissioned by March 1995, while the remaining CEA cleared projects and all "new" projects (that have only been identified until now) will come on stream after 1994/95. As there are very few projects in this shelf that will be commissioned after March 2000, the total capacity additions beyond March 2000 are made up by adding reasonable hydro and other plant capacity (in line with the ratio of additions of various types of generating plant from April 1990 to March 2000).



wise and by type of capacity. As per these projections, the share of hydro capacity falls from 28.7% in March 1990 to about 25.7% in March 2010. The share of total coal-fired thermal capacity (with oil support) reduces from 65% to less than 60%; while gas-based turbine (GT) and combined cycle plant (CCP) capacity increases from 3.7% to 9.6%.

**Table 3.8. Power generating capacity additions (MW)**

		Upto	Apr 1990/ Mar 1995	Apr 1995/ Mar 2000	Apr 2000 Mar 2005	Apr 2005/ Mar 2010
		Mar 1990				
NR	Hydro	5942	1768	5418	5429	3421
	Coal TPS	11140	1790	4520	5940	9440
	GT/CCP	1218	2030	1233	300	477
	Nuclear	675	470	470	1000	1589
	Total	18975	6050	11641	12669	14927
WR	Hydro	2248	1303	250	1223	1900
	Coal TPS	15644	2870	4750	4960	7883
	GT/CCP	717	2398	1845	900	1430
	Nuclear	420	470	0	500	795
	Total	19029	7041	6845	7583	12008
SR	Hydro	8060	1145	1215	598	1431
	Coal TPS	7043	2100	3520	4820	7660
	GT/CCP	30	863	478	290	461
	Nuclear	470	0	470	940	1494
	Total	15602	4108	5683	6648	11046
ER	Hydro	1370	1371	82	1310	2604
	Coal TPS	6654	5285	4020	4548	7227
	GT/CCP	190	0	0	0	0
	Nuclear	0	0	0	0	0
	Total	8214	6656	4102	5858	9831
NER	Hydro	421	371	422	720	2367
	Coal TPS	413	0	0	0	0
	GT/CCP	203	912	1062	1000	1589
	Nuclear	0	0	0	0	0
	Total	1036	1283	1484	1720	3956
All India	Hydro	18042	5957	7387	9279	11723
	Coal TPS	40893	12045	16810	20268	32210
	GT/CCP	2358	6203	4618	2490	3957
	Nuclear	1565	940	940	2440	3878
	Total	62587	25145	29754	34477	51768

Capacity additions envisaged for until March 2000 are estimated largely on the basis of specific projects that have been identified. In particular, these include : (i) projects that have already been sanctioned or/and are under construction; (ii) those which have not yet been sanctioned but have at least been cleared in principle by the Central Electricity Authority (CEA); and (iii) those projects or schemes that have only been identified until now, but on which a final decision on financial support (from the Plan budget) is still awaited.

The investment norms estimated from data obtained from CEA and Planning Commission are as follows: \$ 944/kW for hydro capacity, \$ 889/kW for nuclear, \$ 833/kW for coal-fired TPS capacity, and \$ 583/kW for GT/CCP capacity. These figures are in 1990/91 prices. Capital costs are also assumed to escalate by 7.5% per annum in real terms up to the year 2000 and 5% thereafter to the year 2010.

Although the Government of India (1980) had recommended that 50% of all investment in the power subsector should be for transmission and distribution (T&D) projects, about 60% of the investment in the 1980s was on installing new generation capacity. Therefore, it is assumed that 60% of all future planned investments in the power subsector will be for capacity expansion. The remainder 40% will be split equally between transmission and distribution.

Based on projections for installed capacity, gross and net generation levels are estimated (Table 3.9). These are derived as follows : (i) for hydro power capacity, the gross generation is assumed to be 2900 kWh/kW of installed capacity and auxiliary consumption about 1% of gross generation; (ii) for coal-fired thermal capacity (which uses unwashed coal), annual gross generation is 4900 kWh/kW and auxiliary consumption is 10% of gross generation; (iii) for gas-fired GT and CCP capacity, the gross generation is 7000 kWh/kW with auxiliary consumption being about 2.5% of gross generation; and (iv) for nuclear capacity, the gross generation is 4500 kWh/kW with auxiliary losses being 10% of gross generation.

**Table 3.9.** Projections for gross generation, net generation and sales (GWh)

	1994/95	1999/00	2004/05	2009/10
<b>A Gross generation</b>				
Hydro	69597	91018	117927	151923
Coal TPS	259395	341764	441075	598904
GT/CCP	59925	92251	109681	137381
Nuclear	11273	15503	26483	43932
Total	400190	540535	695165	932141
<b>B Net generation</b>				
Hydro	68901	90107	116747	150404
Coal TPS	233456	307588	396968	539014
GT/CCP	58427	89945	106939	133947
Nuclear	10145	13952	23834	39539
Total	370929	501592	644488	862904
<b>C Sales</b>	285615	386226	496256	664436

It is further assumed that T&D losses will remain more-or-less unchanged from the present day level of 23% of energy despatched from power stations. Table 3.9 also gives the total energy sales projections. It may be noted that these figures correspond only to billable sales -- the actual electricity consumption by consumers will be higher to the extent non-technical or commercial losses occur\*. These "billable" sales are projected to increase from 168,269 GWh in 1989/90 to 664,436 GWh by 2009/10, at the rate of 7.1% per annum.

Fossil-fuel requirements for power generation are also expected to increase (Table 3.10). The underlying assumptions are that: (i) 0.65 kg of coal (INCC) and 15 ml of oil (largely fuel oil) will be required per kWh of gross generation obtained from thermal power station (TPS) units; and (ii) about 0.2815 cu.m. of natural gas will be required (on an average) per kWh of gross generation obtained from GTs and CCPs.\*\*

\* In India, non-technical losses are estimated at over 10% of energy sent out from power stations. In the BAU strategy, this level of non-technical losses is assumed to persist through to 2009/10.

\*\* Although the thermal efficiency of GTs is about 28-30% and that of CCPs (as envisaged at present -- there are no CCPs in operation as yet) is higher at about 43%, an average figure of 35% efficiency in generation is taken. This obviously indicates that both GT and CCP capacity will be in operation in the coming years.

**Table 3.10. Fuel requirements for power generation**

	1994/95	1999/00	2004/05	2009/10
Coal (MT)	168.6	222.1	286.7	389.3
Fuel Oil (000' tonnes)	3793.7	4998.3	6450.7	8759.0
Gas (mcm)	16868.9	25968.6	30875.2	38672.9

Although a detailed analysis of T & D system expansion is necessary, from an engineering point of view alone it is possible to estimate the total lengths of transmission and distribution lines and substation capacities required (Table 3.11). The following assumptions are made on the basis of past data:

- 1) 2.5 km of transmission lines ( $\geq 66$  kV) per MW of installed capacity;
- 2) 16.0 km of sub-transmission and distribution lines ( $\leq 33$  kV) per MW of installed capacity;
- 3) 1.9 MVA of substation capacity for transmission system ( $\geq 66$  kV) per MW of installed capacity;
- 4) 1.8 MVA of substation capacity for subtransmission and distribution system ( $\leq 33$  kV) per MW of installed capacity.

**Table 3.11. T & D system expansion**

	1994/95	1999/00	2004/05	2009/10
$\geq 66$ kV (ckt-km)	62864	74386	86191	129420
$\leq 33$ kV (ckt-km)	409095	487320	566680	847886
$\geq 66$ kV s/s (MVA)	47776	56534	65505	98359
$\leq 33$ KV s/s (MVA)	46023	54824	63752	95387

For purposes of making T&D system expansion projections, it is assumed that with the addition of RET capacity, substation and line capacity only at and below the 33 kV voltage level will need to be augmented, and in the same manner (16 ckt-km/MW of lines and 1.8 MVA/MW of substation capacity).

So far, inter-regional transmission links have been largely for mutual exchange of power between two neighbouring grid systems. However, considering the uneven distribution of the energy resources, generation capacity expansion may be so planned as to overcome deficiencies in one region or state by establishing generating capacity in a neighbouring region

and transmitting bulk power. This approach will enable the consolidation of integrated grid operations.

The projections presented in Tables 3.8 through 3.11 correspond to a 5% GDP growth rate. If GDP were to grow by 6%, it is assumed that only GT/CCP capacity could increase by March 1995, while both TPS and GT/CCP capacity additions may occur thereafter. With this in view, capacity additions during four successive five-year intervals between April 1990 and March 2010 were worked out to be 25873 MW, 32102 MW, 39001 MW and 61405 MW respectively. Total fuel requirements are projected to rise to 435.3 MT of coal, 9.8 MT of fuel oils and 44.2 bcm of gas by 2009/10; and total (billable) sales to 728,137 GWh.

### 3.5 Renewable energy technologies

Although there has been a sharp increase in the funding of Renewable Energy Technologies (RETs) in the last ten years, the fund allocation has remained small in comparison to the energy sector's total outlay. Despite the relatively low investment levels in the R&D and utilisation of RETs in the 1980s, the investment trends do appear encouraging. This perhaps prompted the Department of Non-Conventional Energy Sources (DNES), to propose an extremely ambitious perspective plan in 1987 for renewable energy utilization to the year 2000/01, with an expenditure of about \$26 billion. The proposed targets for power generation using RETs were some 15000 MW by the turn of the century---the major share coming from biomass, wind, small hydro and solar photovoltaic. This target however, is unrealistic and the constraints that are likely to be faced in implementing these programmes have not been adequately addressed by the DNES.

The extent to which a given RET will actually get installed will depend on several factors like the state of technology, future developments, Government policies, economics of generation, infrastructure, industrial capability, organisational and institutional aspects, availability and channelisation of funds and the turnover capacity in national and international markets.

In the BAU strategy, it is assumed that there will be no special drive or effort to set-up significant wattage or number of RET devices, and the existing constraints will continue. On the basis of the potential, level of technology and economics, it appears that only biogas, windfarms and the small and microhydel technologies can play a significant role by the year 2010.

Detailed analysis was carried out to examine the constraints, issues related to grid inter-connection, logistics, turnover capacities within and outside the country, and the future developments in the technology etc. to arrive at realistic values for yearly increments in the installations of these devices. Attempts were made to incorporate all possible factors including the lifetime of devices and a certain phasing out of capacity in arriving at the figures for 2010. The projected installations are given in Table 3.12. All new windfarm capacity additions are assumed to be in the Western, Southern and Eastern regions only, which will account for 45%, 45% and 10% of capacity additions respectively. New small hydro capacity will be added in all regions, as follows: 31% in the Northern Region, 15% in the Western Region, 35% in the Southern Region, 10% in the Eastern Region and 9% in the North-east.

It is assumed that the capacity utilisation factors for windfarms and small hydro installations will be 15% and 22% respectively; their availability factors at times of system peak demand will be 0.1 and 0.3 respectively; their investment costs (in 1990/91 prices) will be \$1654/kW and \$1838/kW respectively, and annual O&M costs at 3.33% and 2% of capital costs respectively.

**Table 3.12.** Projected capacity/installations of RETs by 2010

-----	
<b>Wind energy technologies</b>	
windfarms	650 MW
<b>Mini/Small/Microhydel</b>	
Canal Drop Schemes	850 MW
<b>No. of Biogas Plants</b>	
2 Cubic Meters Capacity	43,64,000
4 Cubic Meters Capacity	42,44,278
<b>Gasifier based power generation</b>	
100-500 kW systems	50 MW
<b>Photovoltaic systems</b>	
Aggregate capacity of systems in all ranges	60 MW
-----	

### 3.6 Biomass fuels

#### 3.6.1 Fuelwood

The supply of fuelwood is difficult to estimate. Current annual figures range anywhere from 66 to 120 MT. Details are given in Chapter 1, Section 2.5.1. Regionwise estimates are shown in Table 1.14.

#### 3.6.2 Crop residues

The quantum of crop residues in a region depend on the cropping pattern and harvesting methods. Estimation of residues has been restricted to important non-fodder crop residues. These are rice husk, maize cob, groundnut shells, cotton sticks, bagasse (of the order of 67 MT/year in 1988-89 - most of which is already used as a thermal source in the sugar industry), coconut-fibre and shell, pulses straw and jute sticks. Projections are shown in Table 3.13.

**Table 3.13.** Regional projections of crop residues (MT/year)

Region	1988-89	1994-95	1999-2000	2000-05	2005-10
Northern	49 662	59 296	68 732	79 679	92.370
Western	32 476	38 777	44 947	52 106	60 405
Southern	37 393	44.647	51 752	59.994	69.550
Eastern	18 514	22 106	25.624	29.705	34 436
North-Eastern	3 004	3 587	4 158	4 820	5 587
Andaman & Others	0 164	0 196	0 227	0 264	0 305
Total	141 214	168 609	195 440	226.568	262 654

#### 3.6.3 Dungcakes

As mentioned in Chapter 1, section 2.5.3, the availability of dung is not going to increase very significantly over the current levels. It is estimated that the annual supply will stabilise by 1994-95 and the amount of wet dung fuel (MT) across regions would be -- Western (63228), Southern (25785), Eastern (92943), Northern (120388) and North Eastern (3) giving a total of 302348 for the country.

### 3.7 Energy shortages

It is clear from the demand forecasts presented in Chapter II, and the supply projections in preceding sections of Chapter III that significant energy shortages will characterize the Indian economy.

The shortages estimated under the BAU strategy of development, under 5% and 6% per annum GDP growth assumptions are given for various energy sources below.

#### Coal shortages

As coal output is not likely to change significantly under the two GDP growth scenarios, coal shortages are higher in the 6% GDP growth case. It is assumed that the poor quality coking coals will be used in industry and utilities as boiler fuel, and that there will be adequate production of prime coking coals to meet a large share of the requirements of the steel industry. It is further assumed that nearly all lignite produced will be used for power generation.

With these assumptions, the net non-coking coal shortages will be as shown in Table 3.14. In the low GDP growth case, marginal shortage (of nearly 30 MT) appears by the year 2009/10. In the high GDP growth case of course, the overall non-coking coal shortages rise to about 153 MT by 2009/10.

**Table 3.14.** BAU strategy - Regional coal shortages (MT/year)

	1994/95	1999/00	2004/05	2009/10
Non-coking coal (5% GDP growth case)				
NR	59.8	77.6	102.7	141.7
WR	15.6	25.0	39.2	69.1
SR	12.6	22.7	35.4	67.2
ER	-71.5	-124.6	-183.4	-247.8
NER	- 0.1	- 1.5	- 0.9	- 0.5
INDIA*	16.4	- 0.8	- 7.0	29.7
Non-coking coal (6% GDP growth case)				
NR	60.8	82.6	115.7	169.8
WR	18.3	33.8	58.7	107.9
SR	14.8	30.4	53.8	105.0
ER	-71.1	-121.7	-175.2	-229.1
NER	- 0.7	- 2.0	- 1.3	- 0.6
INDIA*	22.0	23.1	51.7	153.0

Note: (i) Negative numbers denote surplus supply.  
(ii) The demand for coking coal presented in Chapter 2 is for cleaned coking coal. Washery yields of coking coals are taken as 55% (Source = Dept. of Coal, GOI), middlings as 35% and rejects as 10%. The middlings are of a quality similar to steam-grade non-coking coal, and are assumed to be used for power generation.  
Net imports.



Coal import requirements, particularly in the high GLR growth case are many-folds larger than coal imports at present. Even to physically handle such levels of imports, India would need to undertake a massive effort to develop port facilities, as well as enter into long term import agreements with various coal exporting nations, including Australia and China. Of course, to the extent the quality of imported coal will be better (higher GCV) than that of indigenous coal, the import requirements will be less.

There are of course, inter-regional disparities in the coal availability situation. It is assumed that as at present, coals produced in the Eastern Region will be transported to the Northern, Western and Southern Regions.

### 3.7.2 Oil and gas shortages

India will remain a net oil importer, and will continue importing crude oil and certain refined products (particularly LPG, HSD, LDO, FO and other minor products), but will be in a position to export MS, naphtha and ATF in the low growth case. In the high growth case however, shortages of ATF also appear. Table 3.15 summarizes the net import requirements of crudes and products. As discussed in section 3.3, there will be no gas shortages.

**Table 3.15.** BAU strategy -- Net imports of crude oil and refined products (MT per annum)

	1994/95	1999/00	2004/05	2009/10
<b>5% per annum GDP growth case</b>				
Crude	20.1	30.2	41.4	54.0
Light distillates	1.1	-0.4	-0.6	-1.3
Middle distillates	24.9	31.5	39.6	49.3
Heavy ends	6.5	10.8	14.4	20.3
All products	32.6	42.0	53.4	68.4
<b>6% per annum GDP growth case</b>				
Crude	18.0	25.5	32.7	38.5
Light distillates	2.1	2.0	1.7	-0.4
Middle distillates	27.8	38.2	58.4	63.1
Heavy ends	5.8	8.3	12.6	19.6
All products	35.7	48.6	72.7	82.2

The steep rise in petroleum imports reflects declining self-sufficiency in oil as growth in supplies will not keep pace with demand increases. It is also evident that major efforts will need to be made to curtail the demand for middle-distillates, particularly HSD.

## Power shortages

Power supplies from both RET installations and conventional generating capacities are considered while computing power shortages. In both GDP growth rate cases, power shortages reduce considerably from present levels. In fact, power surpluses also appear in some regions. In this situation, the power surplus regions will export power to neighbouring regions.

According to our projections, both Eastern and Northeastern regions have surplus capacity (Table 3.16).

**Table 3.16. BAU strategy - power shortages (%)**

	1994/95	1999/00	2004/05	2009/10
<b>5% per annum GDP growth case</b>				
<b>(a) % Energy shortage</b>				
NR	11	1	~	~
WR	1	1	7	12
SR	20	20	22	22
ER	1	~	-	-
NER	-	-	-	-
INDIA	6	-	1	1
<b>(b) % Peak shortage</b>				
NR	23	8	3	3
WR	7	7	14	18
SR	23	23	28	30
ER	7	3	-	-
NER	-	-	-	-
INDIA*	15	9	10	10
<b>6% per annum GDP growth case</b>				
<b>(a) % Energy shortage</b>				
NR	23	10	5	-
WR	7	4	11	12
SR	25	24	23	17
ER	1	1	~	-
NER	-	-	-	-
INDIA*	14	7	5	1
<b>(b) % Peak shortage</b>				
NR	33	21	15	9
WR	13	12	18	18
SR	28	28	29	26
ER	15	9	3	-
NER	-	-	-	-
INDIA*	22	16	15	10

~ : below 0.5%

In this situation, power wheeling arrangements may be developed to export surplus power from the Northeast to the South and West (and Northern Region too, if it has shortages) via the Eastern Region. In fact, this may very well reflect the situation that hydropower development in the Northeast accelerates considerably beyond present levels.

#### 3.7.5 Reconciling demand and supply of biofuels

An important characteristic of a biofuel based energy system is that supply is of a localised nature\*. Any accounting, therefore, at the aggregate level is likely to be misleading since scarcity or surplus is at a local level. Consequently, the interventions (which may take the form of supply enhancement, demand management and/or encouraging fuel switching) may be aimed at the wrong target group or area. This caveat should be kept in mind when viewing the supply/demand balance presented at an aggregated level.

The present assessment of the biofuel balances is first carried out at the state level and thereafter aggregated at the regional level. It must however, be reiterated that neither the state nor the region are appropriate levels for designing interventions as far as biofuels are concerned.

- 3.7.5.1 Fuelwood demand and supply: The demand and supply for fuelwood has been dealt with in the individual sections on demand and supply. The demand was found to be significantly higher than the sustainable yields in all states other than those in the north-east. The ratio of the demand to sustainable yields from forests, aggregated to the regional level, are presented in Table 3.17. It must be emphasised, however, that forests are not the only source of fuelwood. There are numerous other sources though there are no reliable data. The National Commission on Agriculture estimated that fuelwood from these sources varies from 50-90% of the total consumption depending on the geographical location of the area in question.

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\* The demand, in general, is also localised except when there are demands from urban and peri-urban areas. These demands and the resulting markets in urban and semi-urban areas for woody biofuels are believed to be among the major causes for deforestation (see for example, CSE 1985).

**Table 3.17.** Ratio of fuelwood consumption to sustainable forest yields

	1991	1995`	2000	2005	2010
North	4.9	5.3	5.7	6.1	6.5
West	2.6	2.8	3.0	3.2	3.4
South	4.6	4.8	5.0	5.2	5.4
East	3.5	3.7	4.1	4.4	4.7
North-East	0.5	0.6	0.7	0.7	0.8
<b>Average</b>	2.8	3.0	3.2	3.4	3.6
<b>(Average excluding NE)</b>	3.7	3.9	4.2	4.4	4.7

One clear implication of Table 3.17 is that intervention for fuel substitution in the rural domestic sector deserves a priority in the Northern parts of the country.

- 3.2 Agricultural residues: As indicated in section 3.6, only non-fodder residues were considered while estimating their availability. The consumption-to-production ratio of the non-fodder residues (Table 3.18), shows that the availability position of the non-fodder residues appears adequate in all the regions except the east and the north-east. It is likely that in these regions, some fodder residues are also being diverted for use as fuels.

**Table 3.18.:** Consumption to production ratios of agricultural wastes

	1995	2000	2005	2010
North	0.25	0.23	0.22	0.20
West	0.16	0.15	0.14	0.13
South	0.28	0.25	0.22	0.20
East	1.02	0.97	0.91	0.86
North-East	0.97	0.91	0.86	0.80
<b>Average</b>	0.35	0.33	0.30	0.28

The use of the ratio as an indicator of supply options may be misleading for one important reason. Some non-fodder residues may already be in use and therefore may not be actually available. A good example is bagasse, most of which already finds use in the sugar industry. Table 3.19 lists the consumption-to-production ratios for the regions after deducting the bagasse production. The country average of the consumption-to-production ratio in this case goes above 0.6, indicating that most of the non-fodder residues already have competing uses as a fuel in the domestic sector.

**Table 3.19.** Consumption to production ratio of agricultural residue (without bagasse)

	1995	2000	2005	2010
North	0.73	0.68	0.63	0.61
West	0.25	0.23	0.21	0.20
South	0.52	0.47	0.42	0.38
East	1.24	1.16	1.10	1.04
North-East	1.26	1.19	1.12	1.05
<b>Average</b>	0.66	0.61	0.57	0.53

Animal waste: Like other biofuels, the supply position of animal wastes does not appear comfortable (Table 3.20). It is however, possible to increase the availability of this waste resource by about 10-25% by increasing the collection efficiency.

**Table 3.20.** Consumption to availability ratio of dung

	1995	2000	2005	2010
North	1.65	1.78	1.92	2.07
West	1.80	1.93	2.07	2.21
South	0.90	0.94	0.99	1.03
East	1.11	1.21	1.31	1.41
North-East				
<b>Average</b>	1.40	1.51	1.63	1.75

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**Environmental impacts of energy development (BAU)**

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**Introduction**

Environmental impacts resulting from energy production and use vary widely. The combustion of fossil fuels results in emissions of pollutants such as particulate matter, oxides of sulphur and oxides of nitrogen which, in addition to affecting the health of human beings, also adversely affect plant and animal life. The construction of a large dam leads to the creation of a reservoir that often results in large scale displacement of people along with the loss of existing forests and agricultural land. Nuclear plants have radiological concerns, the health effects of which can extend to more than one generation.

The diversity of environmental impacts arises not only because of the different types of energy fuels/technologies, but even within the same type, the potential for damage may vary from location to location. Consider, for example, hydroelectric plants. The magnitude of impacts would depend upon various factors such as the terrain and vegetation of the catchment area, the size of the reservoir, the type of area submerged, etc. Again, consider the case for thermal power plants. Although technology-wise there would be little difference, the magnitude of the impact would largely depend upon the location of the plant. If the plant is located in an area where existing levels of pollutants are already high, it would have a greater potential for damage than if it is located in an area with low ambient pollution levels. An example is a city versus a rural siting where, for the former, not only is the ambient air quality often over critical levels but also a greater number of people are exposed to pollution.

In this exercise, wherever applicable, an attempt has been made to capture some of the locational impacts associated with energy activities. A description of the environmental impacts arising from the BAU strategy for the five regions is given in the sections that follow.

## 4.2 Environmental impacts of energy production

### 4.2.1 Coal mining and thermal power generation

4.2.1.1 Coal mining: The environmental impacts from coal mining include loss of forest cover, loss of production (forest, agriculture and grasslands), loss of topsoil and soil erosion, surface water pollution, lowering of water table, hazards of ore transport (damage to vegetation, soil, drainage, agriculture, water quality), sediment production and discharge, fire hazards and air pollution and displacement of people.

Since coal production is predicted to remain the same under 5 and 6 per cent GDP growth rates, the impacts from coal mining also would remain the same. The total spread of coalfields in India is over 3.47 Mha while the extent of area under coal mining till 1989-90 was of the order of 23,269 ha (GOI, 1989). The average amount of forest land depleted per tonne of coal production has been determined regionwise. Using these figures in conjunction with production estimates up to the year 2010, the total amount of forest land depleted is given in Table 4.1. The maximum forest area lost is in the eastern region the damaged forest type being of the Tropical Dry Deciduous type.

**Table 4.1.** Projections of additional forest area depleted  
(5 % GDP growth rate)

Region	Average area (ha/MT)	94/95	99/2000	2004/05	2009/10	Total	Forest type
-----							
West	229.10	4822	2109	2508	2011	11450	TDD+TMD
South	742.37	9652	2544	2249	1909	16355	TMD
East	141.32	8567	7021	8242	10092	33922	TDD
North- east	97.83	204	87	0	0	291	TWE
All India		23245	11761	13000	14012	62018	
-----							
TDD: Tropical dry deciduous							
TMD: Tropical moist deciduous							
TWE: Tropical wet evergreen							

The impact of coal mining in terms of the number of families displaced has been estimated based on the following norms: opencast, 173/MT of coal; underground, 32/MT of coal (GOI 1988). These are presented in Table 4.2.

**Table 4.2.** Number of families displaced  
(5 % GDP growth rate)

Region	90/91- 94/95	95/96- 99/2000	2000/01- 04/05	05/06- 09/10	Total from 90/91-2009/10
West	3649	2277	2393	1787	10106
South	1640	642	688	539	3508
East	6954	6160	7906	8944	29964
North- east	324	160	0	0	494
All India	12568	9239	10986	11270	44063

Abandoned coal mining operations in the past have left more than 10 000 ha of land totally damaged due to subsidence of surface land and mine spoil dumps. Though the government has laid down certain standards to be followed by mining companies, these are generally not complied with. Based on normative estimates of 0.0003 ha of land damage per tonne of coal output and assuming that 90% of the lifetime overburden is used for refilling the excavated mines, it is estimated that by the year 2010, another 7 000 ha of land would be affected by mine spoil dumps. Regionwise details are presented in Table 4.3. These estimates do not include the area damaged due to subsidence and therefore are on the lower side.

**Table 4.3.** Projections of area required for external dump  
(5 % GDP growth rate)

Region	94/95	99/2000	04/05	09/10	Total
	(in ha)				
West	633	395	415	310	1753
South	260	111	119	93	583
East	1067	972	1285	1417	4741
North- east	55	28	0	0	83
All India	2015	1506	1819	1820	7160



4.2.1.2 Thermal power plants. The bulk of Indian coal is characterized by high ash (30-40%) and low sulphur content (below 0.5% except for northeastern coal), the combustion of which produces large quantities of flyash and bottom-ash. The particulate matter in the flue gas is controlled by Electrostatic Precipitators (ESP), the new units having efficiencies that are over 99%. The solid waste products from combustion (consisting of flyash removed from the ESP and the bottom-ash) pose a major waste disposal problem because of large areas of land that are required and the consequent deterioration of soil quality.

4.2.1.3 Impact on air quality. Before discussing the impacts of power plants on air quality, the general approach adopted for capturing local aspects of air pollution is presented. Air pollution has local, regional and global ramifications, the concerns being impact on human health, ecosystem degradation due to acid rain, and the consequences of global warming, respectively. Local impacts are site specific, the damage potential of the energy activity depending upon the additional pollutant load and the current ambient air quality. These impacts are usually estimated using dispersion models based on technical (emission rates, design features, etc.) and on meteorological features (wind direction, atmospheric stability, etc.). This kind of an exercise, however, is well beyond the scope of this study. Instead, a more simplistic approach has been developed for this study wherein a region is mapped into three zones, based on the damage potential. These are (1) areas that are heavily polluted, (2) areas that are moderately polluted, and (3) areas that are relatively clean. Based on the data available for 33 cities in India, it was seen that only TSP levels exceeded the standards, with both  $\text{SO}_x$  and  $\text{NO}_x$  on an average being well within the standards (with the exception of two cities). Therefore, these zones have been defined based on TSP levels as follows:

Zone 1: Heavily polluted areas, where ambient annual average TSP levels are above  $200 \text{ mg/m}^3$  (1991 proposed standards).

Zone 2: Moderately polluted areas, where ambient annual average TSP are between  $150$  to  $200 \text{ mg/m}^3$ .

Zone 3: Relatively clean areas, where the ambient annual average TSP levels are below  $150 \text{ mg/m}^3$ .

This zoning scheme has also been followed wherever impacts on air quality have been determined.

Emissions from thermal power plants are given for all the zones and regions in Table 4.4 (5% GDP growth rate). Since location specific expansion plans were available for the

period 1990-2000, these have been mapped into the respective zones. For the remaining period, it is assumed that no new plants will be located in Zone 1 (critical zone). The capacities have been distributed in the ratio of 1:2 for Zone 2 and Zone 3 respectively.

**Table 4.4. Emissions from thermal power plants**

(thousand tonnes) (5 % GDP growth rate)

	SO <sub>x</sub>			CO			NO <sub>x</sub>			TSP			HC		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1990	106	84	36	3	2	1	111	88	38	3114	2464	1073	2	1	1
1995	122	100	72	3	2	2	128	105	76	3584	2934	2137	2	1	2
2000	198	148	120	5	3	3	208	155	126	5824	4345	3548	3	2	3
2005	198	227	278	5	5	7	208	234	284	5824	6563	7983	3	3	5
2010	198	347	517	5	8	13	208	360	535	5824	10087	15032	3	5	9
1990	119	120	141	3	3	4	125	126	148	3496	3531	4150	2	2	2
1995	135	158	196	3	4	6	142	166	206	3966	4651	5774	2	3	3
2000	213	234	393	5	6	11	223	246	412	6251	6891	11564	3	4	6
2005	213	297	519	5	8	14	223	312	544	6251	8743	15268	3	5	8
2010	213	397	719	5	11	19	223	417	754	6251	11686	21154	3	7	11
1990	68	34	28	2	1	1	72	35	29	2016	988	813	1	1	0
1995	116	34	60	3	1	2	122	35	63	3427	988	1754	2	1	1
2000	202	66	79	5	2	3	212	69	83	5958	1929	2312	3	2	1
2005	202	127	201	5	4	6	212	133	211	5958	3729	5911	3	3	3
2010	202	224	395	5	7	11	212	235	415	5958	6589	11631	3	5	6
1990	96	0	85	3	0	2	101	0	89	2826	0	2501	2	0	1
1995	142	0	240	4	0	6	149	0	252	4181	0	7065	3	0	4
2000	212	0	323	6	0	8	222	0	339	6242	0	9507	4	0	5
2005	212	58	438	6	2	11	222	61	460	6242	1698	12903	4	1	7
2010	212	150	621	6	4	16	222	157	652	6242	4396	18299	4	3	10
1990	0	0	13	0	0	0	0	0	13	0	0	367	0	0	0
1995	0	0	13	0	0	0	0	0	13	0	0	367	0	0	0
2000	0	0	13	0	0	0	0	0	13	0	0	367	0	0	0
2005	0	0	13	0	0	0	0	0	13	0	0	367	0	0	0
2010	0	0	13	0	0	0	0	0	13	0	0	367	0	0	0

ne 1, 2 : Zone 2, 3 : Zone 3

It can be seen from Table 4.4 that by the year 200 emissions from thermal power plants in Zone 1 would be similar in all regions except the north-east. In the other two zones, emissions would be the highest in west, with those in the east and south being comparable. Table 4 shows the emissions from thermal power plants under the BAU scenario.

**Table 4.5. Emissions from thermal power plants**

(thousand tonnes)  
6  
(% GDP growth rate)

		SO <sub>x</sub>			CO			NO <sub>x</sub>			TSP			HC		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
North																
	1990	106	84	36	3	2	1	111	88	38	3114	2464	1073	2	1	1
	1995	122	100	72	3	2	2	128	105	76	3584	2934	2137	2	1	2
	2000	220	164	133	6	3	3	231	172	140	6465	4823	3938	3	2	3
	2005	236	270	331	6	6	8	248	278	338	6931	7810	9500	4	4	6
	2010	248	434	646	6	10	16	260	450	669	7280	12609	18790	4	6	11
West																
	1990	119	120	141	3	3	4	125	126	148	3496	3531	4150	2	2	2
	1995	135	158	196	3	4	6	142	166	206	3966	4651	5774	2	3	3
	2000	121	133	224	3	3	6	127	140	235	3563	3928	6591	2	2	3
	2005	251	350	612	6	9	17	263	368	642	7376	10317	18016	4	6	9
	2010	264	492	892	6	14	24	277	517	935	7751	14491	26231	4	9	14
South																
	1990	68	34	28	2	1	1	72	35	29	2016	988	813	1	1	0
	1995	116	34	60	3	1	2	122	35	63	3427	988	1754	2	1	1
	2000	220	72	86	5	2	3	231	75	90	6494	2103	2520	3	2	1
	2005	244	154	243	6	5	7	257	161	255	7209	4512	7152	4	4	4
	2010	259	287	506	6	9	14	271	301	531	7626	8434	14888	4	6	8
East																
	1990	96	0	85	3	0	2	101	0	89	2826	0	2501	2	0	1
	1995	142	0	240	4	0	6	149	0	252	4181	0	7065	3	0	4
	2000	235	0	359	7	0	9	246	0	376	6929	0	10553	4	0	6
	2005	261	71	539	7	2	14	273	75	566	7678	2089	15871	5	1	9
	2010	276	195	807	8	5	21	289	204	848	8115	5715	23789	5	4	13
North-east																
	1990	0	0	13	0	0	0	0	0	13	0	0	367	0	0	0
	1995	0	0	13	0	0	0	0	0	13	0	0	367	0	0	0
	2000	0	0	13	0	0	0	0	0	13	0	0	367	0	0	0
	2005	0	0	13	0	0	0	0	0	13	0	0	367	0	0	0
	2010	0	0	13	0	0	0	0	0	13	0	0	367	0	0	0

1 : Zone 1, 2 : Zone 2, 3 : Zone 3

4. Impacts on land: It is estimated that approximately 200 ha of land are required for the disposal of ash from a 210 MW plant (Mathur, 1989a). Based on this, the additional land requirements for ash disposal from new power plants till the year 2010 under both GDP growth rates are given in Table 4.6.

**Table 4.6.** Land requirement for ash disposal for new plants (BAU) in ha

Region	GDP growth rate	
	5%	6%
North	8242	9767
West	7776	9011
South	6878	8222
East	8010	9398
North-east	0	0

In Singrauli, out of a total area of 313,183 ha in 1981, arable land occupied 36%, i.e. 113,416 ha. Of this, 18% was cultivable wasteland and 82% of the area was under cultivation. Approximately 1,327 ha was acquired till 1990 for setting up five ash ponds.

- 1.5 Impact on soil quality: The impact of an operating thermal power plant on the soil environment and in turn on agricultural production could be either due to the direct impact of release of air pollutants (such fly ash) or due to use of agricultural land for siting of plant, transmission corridor and ash ponds.

Fallout estimations from a thermal power plant indicate that 80-90% particle deposition occurs within a 5-10 km radius from the source. Since this deposition of particulate matter goes on all the time, it results in alteration of physico-chemical properties of soils in the vicinity.

Studies have looked at physico-chemical characteristics of garden soils to which various concentrations of fly ash were added (Thakre and Thergaonkar 1985). Water-holding capacity of garden soil is 68.77% while that of fly ash is 52%, showing an 18% reduction. pH does not show any significant variation. Conductivity value for soil is 155 micromhos/cm and increases as the fly ash percentage increases, as compared to 320 micromhos/cm for pure fly ash extract. An increase in percentage of flyash in soils causes a decrease in total exchangeable cation capacity, which is an index of decline in soil fertility.

The operation of coal-based plants brings about changes in trace elements and radio nuclides in soils in the vicinity. Studies have examined alterations in natural radioactivity of soils around certain thermal power plants (Ramachandran et al. 1990). Concentrations of  $^{228}\text{Th}$ ,  $^{226}\text{Ra}$  and  $^{40}\text{K}$  were determined (relative to countrywide average of natural radioactivity content in soils) in vicinity of the plants and within a 200 km radial distance. Those thermal power plants with a higher capacity would be more likely to have soils with a higher radioactivity content around them, but it would also depend on the age of the plant as well as the natural radioactivity of the soils. Data indicate that there is no relationship between the radial distance from the thermal power plants and soil radioactivity, indicating that fly ash emissions do not modify soils at distant sites to a similar extent. Since soils of a region vary widely, the impact is extremely site specific.

- 4.2.1.6 Impact on water quality: According to the Central Pollution Control Board, the total wastewater discharge from a thermal power plant can be as high as 100 kl per day per megawatt of power generated. The Biological Oxygen Demand (BOD) in this wastewater can be as high as 150 mg/l. If a 1000 MW plant discharges this large amount of waste water with such a high BOD in a river that has an annual average discharge of 3000 million  $\text{m}^3$ , the increase in BOD of the river water is 1.8 mg/l, which is low. If, however, a cluster of power plants is located in an area that drains into a relatively small river, BOD pollution can be significant. At least three locations in the country could be facing such a problem: the Damodar Valley, the Singrauli region and the National Capital Region. The increased BOD loadings from thermal power plants in these areas could reduce Dissolved Oxygen (DO) in the receiving waters making them unsuitable for aquatic life as well as for other useful purposes. At most other places, as far as BOD is concerned, the impact of thermal power plants on the surrounding water quality would be fairly low.

Damodar valley is a highly stressed area due the combined impacts of coal mining and washing and thermal power generation. In addition, energy intensive industries such as steel and fertilizer are also located in the valley. The BOD concentration in the Damodar river varies between 1.5 and 3.4 mg/l. The average annual flow through the river basin is 12210 million  $\text{m}^3$ . Additional coal mining and power generation are bound to add to the BOD of the river. The Total Suspended Solids (TSS) concentration in the river is similarly high, ranging between 55 and 105 mg/l. Additional power generation

will result in higher TSS concentrations which will exceed the Indian Standard of 100 mg/l. In the Singrauli region, five coal based super-thermal power plants generate over 5000 MW of power. The raw water source for these plants is the Gobind Ballabh Pant Sagar or the Rihand reservoir. The reservoir is also used as a cooling pond for hot water discharges from the five plants, giving rise to thermal pollution. Increased temperature results in a decrease in the DO concentrations, especially in the deeper regions of the reservoir, making them unfit for fish life.

In the National Capital Region, coal-based plants generate about 1500 MW of power. By the year 2000, this figure is expected to be close to 3000 MW. The DO and BOD levels in the river Yamuna are acceptable in Panipat but critical in Delhi. In Delhi, the DO has been as low as 0.8 mg/l and BOD as high as 20 mg/l during the period 1984 to 1988. Although most of this pollution can be attributed to domestic wastewater, additional BOD load on the Yamuna is clearly undesirable regardless of the source.

## 1.2.2 Oil exploration and refining

1.2.2.1 Oil exploration: Other than a potential blow-out, the major source of environmental concern from hydrocarbon exploration and production is the spillage of drilling fluids into the environment.

Table 4.7 provides an estimate of the discharge of drill cuttings and mud chemicals from exploration drilling activity in 1991 and that projected for 2009/10 for the 5% GDP growth rate scenario.

**Table 4.7.** Discharge of drill cuttings and mud chemicals from off-shore exploration and drilling activity  
(5% GDP growth rate)

Basins	(thousand tonnes)			
	Drill Cuttings		Chemicals	
	1990/91	2009/10	1990/91	2009/10
K-G	2.7-4.3	4.5-7.2	1.2-3.8	2.0-6.3
Cauvery	5.4-8.6	2.7-4.3	2.4-7.6	1.2-3.8
Bengal	1.8-2.9	5.4-8.6	0.8-2.5	2.4-7.6
K Saurashtra	-	4.5-7.2	-	2.0-6.3
K-K	-	13.5-21.5	-	6.1-19.3
Mahanadi	-	9.9-15.7	-	4.4-14.0
Andaman	-	3.6-5.7	-	1.7-5.1
Bombay	28.0-44.3	61.4-97.2	12.6-39.2	28.0-86.0

It is difficult to quantify the magnitude of the impact from such discharges because the dispersion and dilution of such discharges will vary according to the ambient water condition, composition of drilling fluids and the rates and duration of drilling fluid and cutting discharges. Table 4.7 serves to indicate the magnitude of the problem. It was not possible to measure impacts because of the lack of more detailed baseline data.

At a general level, it can be stated that the extent of impact will depend on the distance of the drilling activity from the coast. For example, most of the activity occurring in Bombay High is at a distance of 66 km from the coast and hence little impact would be felt on the coast from such discharges. Adverse impacts on water column organisms are expected to be minor and of short duration. Effects on sessile organisms is limited to a short distance from a discharge point.

If drilling activity is closer to the coast as for example in Palk Bay or is close to major estuaries/deltas, then the impacts will tend to be more significant as the extent of dispersion and dilution of the discharges will be limited.

4.2.2.2 Oil refineries: A comparison of TSP, SO<sub>x</sub> and NO<sub>x</sub> emitted from a typical refinery (6 MT) and a 1000 MW coal based power plant shows negligible TSP emissions along with lower levels of SO<sub>x</sub> and NO<sub>x</sub>. Therefore, a refinery by itself will not significantly affect air quality, a conclusion also observed in studies conducted for a refinery located at Mathura (Centre for Science and Environment, 1985). However, if located in an already polluted zone, the impacts will be significant. Refineries operating today are spread over the five regions with roughly half of them located in Zone 1 areas, one-third in Zone 2 and the remaining one-sixth of capacity in Zone 3. It is assumed that all future refineries after the year 2000 will be located in Zone 2 (one-third of capacity) and Zone 3 (the remaining two-third of capacity).

Emissions from refineries for the BAU strategy are given in Table 4.8 for the 5% scenario. Since refinery capacity remains the same under the 6% scenario, the emissions also remain the same.

The discharge of refinery effluents has a significant adverse impact on the receiving water body. A typical refinery (6 MT/annum) discharging into a river of 400 bcm flow will increase the BOD by approximately 1.5 mg/l. In comparison, a 1000 MW coal based plant at the same location would have an impact that would approximately be lower by an order of magnitude.

The two largest refineries in India, Koyali and Mathura, process 9.5 and 7.5 MT of crude per year respectively. While

the Mathura refinery will increase the BOD in the Yamuna by 4.15 mg/l, the Koyali refinery will raise the BOD in the Narmada by 2.1 mg/l. Since the magnitude of impact depends largely on the characteristics of the receiving water body, it is difficult to extend the analysis to new refineries being planned under the BAU strategy, given the absence of information on their siting.

**Table 4.8. Emissions from oil refineries (tonnes)**

(Tonnes)

	SO <sub>x</sub>			CO			NO <sub>x</sub>			TSP			HC		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1990	0	190	0	0	37	0	0	1330	0	0	3	0	0	9383	0
1995	0	190	152	0	37	28	0	1330	1064	0	3	2	0	9383	7506
2000	0	223	219	0	43	40	0	1561	1533	0	3	3	0	11013	10816
2005	0	262	299	0	51	55	0	1838	2095	0	3	4	0	12967	14782
2010	0	317	411	0	61	75	0	2226	2882	0	4	5	0	15702	20336
1990	481	0	0	97	0	0	3369	0	0	4	0	0	23771	0	0
1995	481	0	0	97	0	0	3369	0	0	4	0	0	23771	0	0
2000	481	33	67	97	6	12	3369	231	469	4	0	1	23771	1630	3309
2005	481	72	147	97	13	27	3369	508	1031	4	1	2	23771	3584	7276
2010	481	128	259	97	23	48	3369	896	1818	4	2	3	23771	6319	12830
1990	114	142	114	37	22	37	798	993	798	1	1	3	5630	7006	5630
1995	114	142	190	37	22	51	798	993	1330	1	1	4	5630	7006	9383
2000	114	174	257	37	28	63	798	1224	1799	1	2	4	5630	8636	12693
2005	114	214	337	37	36	78	798	1501	2361	1	2	5	5630	10590	16659
2010	114	269	449	37	46	99	798	1889	3148	1	3	7	5630	13325	22213
1990	69	83	0	0	0	0	488	585	0	1	2	0	3440	4128	0
1995	69	83	0	0	0	0	488	585	0	1	2	0	3440	4128	0
2000	69	116	67	0	6	12	488	816	469	1	2	1	3440	5758	3309
2005	69	156	147	0	13	27	488	1093	1031	1	3	2	3440	7712	7276
2010	69	211	259	0	23	48	488	1481	1818	1	3	3	3440	10447	12830
1990	0	0	68	0	0	0	0	0	479	0	0	1	0	0	3378
1995	0	0	144	0	0	14	0	0	1011	0	0	2	0	0	7131
2000	0	0	244	0	0	32	0	0	1711	0	0	3	0	0	12070
2005	0	0	363	0	0	54	0	0	2550	0	0	4	0	0	17990
2010	0	0	531	0	0	85	0	0	3725	0	0	6	0	0	26280

reast

One 1, 2 : Zone 2, 3 : Zone 3



#### 4.2.3 Hydropower

Of the nearly 50,000 MW of installed capacity that will be added in the next 20 years, approximately 95% will be in medium and large size dams and therefore may have the potential for causing considerable environmental and social impacts. The remaining 5% will be created by small dams that will not lead to any major environmental disruption.

These environmental and social impacts are a direct result of dam construction and the consequent formation of a reservoir. Among the impacts, the significant ones include displacement of people, submergence of agricultural and forest land, increased seismic activity leading to a dam failure and the prevalence of water-borne diseases.

Table 4.9 shows the extent of submergence of forests and displacement of people for 29 dams that have been sanctioned and are included in the BAU strategy. These dams constitute nearly 35% of the installed capacity.

The data clearly show the large variation that exists in the relationship between the installed capacity and the submergence of forests and displacement of people. The impacts are extremely site specific. For instance, forest submergence varies from 0.01 ha/MW in the case of Teesta (1200 MW) and Maneri (304 MW) to 22.45 ha/MW for the Narmada and Sardar Sarovar Project (2450 MW). Similarly, displacement too shows a very large variation ranging from no displacement as in the case of Srisailem (990 MW) to 288 people/MW as in the case of Bansagar (348 MW). Hence, it is extremely difficult to extend the analysis of environmental impacts to dams where site specific details are not available (remaining 65% of capacity).

The most immediate social impact of large dams is large scale displacement of people. The oustees lose their houses, land, property and other tangible assets. Although compensation is given, the problem of implementation, and in some cases the rehabilitation package by itself, fail to adequately compensate the oustees. Moreover, as past records show, when oustees are rehabilitated, they are almost never moved en block but are scattered, thus making it more difficult for them to re-establish their community life. Of the 16,000 families that were displaced because of the Pong dam in the hills of Himachal Pradesh, 6000 families were given land in the command area of Indira Gandhi Canal in the Rajasthan desert, which was a complete change of cultural and climatic environment for the oustees. The issue of rehabilitation becomes more serious when the number of displaced people is very large as in the case of Narmada and Sardar Sarovar projects, where 300,000 people are to be ousted from their homelands.

**Table 4.9. Submergence and displacement in dam sites**

Region	Capacity (MW)	Displacement (No.of people)	Forest submerged (ha)	Affected forest type
<b>NORTH</b>				
Salal	345	-	0	STDE
Chamera	540	-	785	TDD
Dhauliganga	280	550	19.2	TDD
Sawalkot	600	2460	165.5	STDE
Uri	480	1070	0	STP
Dulhasti	390	0	0	STDE
Baglihar	450	1370	12.82	STDE
Thein	600	9595	852	TDD
Srinagar	330	0	202.84	STP
Vishnuprayag	480	0	80	HMT
Lakwarvyasi	420	3502	699	TDD
Maneri 2	304	150	2	HMT
Naphtajhakri	1500	750	0	STP
Kohl	800	2652	989.3	STP
Tehri	1000	46000	1600	STP
Kishau	600	2403	3031	STP
<b>WEST</b>				
Bansagar	348	100000	4478	TMD
Koyna stg IV	1000	0	80	TMD
Narmada&				TMD
S.Sarovar	2450	300000	55000	TMD
Hasdeobango	120	12500	10250	TMD
Ghatghar	250	300	91	TMD
<b>SOUTH</b>				
Srisailam	990	0	0	TDD
Kalinadi	270	1979	1214.5	TMD
Puyankutty	240	87	1900	TMD
<b>EAST</b>				
Ramman	50	600	0	TMD
Koel karo	710	25000	1003	TMD
Upper indra- vati	600	17500	708	TMD
<b>NORTH-EAST</b>				
Rangit	60	225	6.5	MWT
Teesta	1200	40	12	MWT

STDE: Sub-tropical Dry Evergreen; STP: Sub-tropical pine;  
TDD: Tropical Dry Deciduous; TMD: Tropical Moist Deciduous;  
HMT: Himalayan Moist Temperate; MWT: Montane Wet Temperate.

Loss of forests implies a loss of all benefits that a forest provides e.g. prevention of soil erosion, production

of oxygen, recycling of water and controlling humidity, absorption of carbon dioxide and sheltering of birds. The largest submergence of forests is seen in the Narmada Sagar, Hasdeobango, Tehri and Kishau dams. The large quantity of water impounded in the reservoir increases the local mass and the pressure thus created may be enough to increase or initiate seismic activity near the dam area. Earthquakes can cause a dam to collapse and cause further devastation downstream. However, most dams are designed to withstand earthquakes. In India, out of more than 1800 large dams, only two, Koyna and Bhatsa in Maharashtra, are known to have experienced earthquakes. The earthquake in Koyna in 1967 was more significant (6.7 on the Richter scale against 4.5 in the case of Bhatsa dam). The Koyna earthquake claimed 200 lives and injured 1500 people. The Tehri dam lies in a region of high seismic potential. A failure of the dam would be catastrophic, especially considering the fact that a densely populated area lies downstream. The earthquake that occurred in Uttarkashi (a neighbouring district) in October 1991 stresses the need to re-examine the safety of the dam.

#### **4.3 Environmental impacts of energy use**

##### **4.3.1 Industrial Sector**

The major pollutants from industries have their source in process wastes. However, for the purpose of this study, only air pollution resulting from the combustion of various fuels has been considered. The industries that were examined for their pollution potential are as follows: textile, chemical and petrochemical, aluminium, iron and steel, mini-steel, cement, fertilizer, paper, sponge iron and machinery. Estimates of high speed diesel, light diesel oil, fuel oil, low stock high sulphur fuel, coal, naphtha, natural gas and petroleum products to be used in the industrial sector are those given in Chapter 2.

It was assumed that all iron, steel and cement units are located in the critical zone (Zone 1). Aluminium and paper units have been located in Zone 3. Fertilizer plants are usually sited in locations that correspond to Zone 2. Chemical and petrochemical plants are located by and large in the west and east. We have assumed that no such unit will be located in Zone 1 and that the capacities will be distributed in the ratio 1:2 in Zone 2 and Zone 3. Tables 4.10 and 4.11 show emissions from the industrial sector for the 5 and 6% scenarios respectively.

**Table 4.10. Emissions from the industrial Sector**

(5% GDP growth rate)

	sox(000t)			co(000t)			nox(000t)			tsp(000t)			hc(000t)		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1990	41	4	27	1	0	1	36	1	18	929	1	241	0	0	0
1995	58	5	37	2	0	1	52	3	25	1324	1	338	0	0	0
2000	77	8	35	2	0	1	70	3	23	1790	2	201	0	0	0
2005	105	11	40	3	0	1	95	5	28	2435	3	211	0	0	0
2010	143	16	47	4	0	1	129	7	35	3316	4	223	0	0	0
1990	149	26	34	4	1	1	134	9	25	3454	7	390	0	0	0
1995	206	42	46	5	1	1	186	21	33	4810	153	484	0	0	0
2000	248	59	42	6	1	1	223	34	30	5728	340	306	0	0	0
2005	319	78	46	8	2	1	287	45	36	7352	434	329	0	0	0
2010	407	106	53	10	2	1	366	63	43	9314	554	355	0	0	0
1990	121	7	24	3	0	1	115	2	17	3067	2	298	0	0	0
1995	162	14	33	4	0	1	153	8	23	4079	103	380	0	0	0
2000	212	18	36	5	0	1	202	10	24	5361	104	334	0	0	0
2005	256	24	43	7	1	1	242	14	28	6393	134	364	0	0	0
2010	335	34	54	9	1	1	315	20	35	8291	169	397	0	0	0
1990	198	3	10	5	1	1	192	8	8	5178	6	161	0	0	0
1995	222	49	15	6	1	1	216	14	12	5828	183	245	0	0	0
2000	236	60	15	6	1	1	224	35	12	5979	588	220	0	0	0
2005	270	84	17	7	2	1	252	47	13	6651	752	232	0	0	0
2010	325	116	20	8	3	1	298	63	16	7795	964	246	0	0	0
1990	2	1	2	0	0	0	1	0	1	25	0	15	0	0	0
1995	2	1	6	0	0	0	2	0	5	37	0	107	0	0	0
2000	3	1	6	0	0	0	2	0	5	54	0	88	0	0	0
2005	4	2	6	0	0	0	3	1	5	76	0	82	0	0	0
2010	6	2	6	0	0	0	5	1	5	104	1	77	0	0	0

, 2 : Zone 2, 3 : Zone 3

**Table 4.11. Emissions from the industrial sector**

(thousand tonnes)

(6% GDP growth rate)

		sox(000t)			co(000t)			nox(000t)			tsp(000t)			hc(000t)		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
north	1990	41	4	27	1	0	1	36	1	18	929	1	241	0	0	0
	1995	53	5	35	1	0	1	46	1	23	1191	1	309	0	0	0
	2000	67	7	44	2	0	2	59	2	30	1528	2	396	0	0	0
	2005	86	8	57	2	0	2	76	2	38	1959	2	508	0	0	0
	2010	111	11	73	3	0	3	97	3	49	2512	3	652	0	0	0
west	1990	149	26	34	4	1	1	134	9	25	3454	7	390	0	0	0
	1995	191	33	44	5	1	1	172	12	32	4429	9	500	0	0	0
	2000	245	43	56	7	2	2	220	15	41	5680	12	641	0	0	0
	2005	314	55	72	8	2	2	283	19	53	7284	15	822	0	0	0
	2010	403	70	92	11	3	3	362	24	68	9341	19	1055	0	0	0
south	1990	121	7	24	3	0	1	115	2	17	3067	2	298	0	0	0
	1995	155	9	31	4	0	1	147	3	22	3933	3	382	0	0	0
	2000	199	12	39	5	0	2	189	3	28	5044	3	490	0	0	0
	2005	255	15	51	6	0	2	243	4	36	6468	4	628	0	0	0
	2010	327	19	65	8	0	3	311	5	46	8294	5	806	0	0	0
east	1990	198	3	10	5	1	1	192	8	8	5178	6	161	0	0	0
	1995	254	4	13	6	1	1	246	10	10	6640	8	206	0	0	0
	2000	326	5	16	8	2	2	316	13	13	8515	10	265	0	0	0
	2005	418	6	21	11	2	2	405	17	17	10920	13	340	0	0	0
	2010	535	8	27	14	3	3	519	22	22	14003	16	435	0	0	0
northeast	1990	2	1	2	0	0	0	1	0	1	25	0	15	0	0	0
	1995	3	1	3	0	0	0	1	0	1	32	0	19	0	0	0
	2000	3	2	3	0	0	0	2	0	2	41	0	25	0	0	0
	2005	4	2	4	0	0	0	2	0	2	53	0	32	0	0	0
	2010	5	3	5	0	0	0	3	0	3	68	0	41	0	0	0

1 : Zone 1, 2 : Zone 2, 3 : Zone 3

It is seen that emissions from industries are the highest in the west. East and south have somewhat similar emissions levels.

#### 4.3.2 Transport sector

The most widespread and significant impacts of oil utilization come from mobile sources. With the sharp increase in the number of motorcycles, scooters, automobiles, vans, trucks and buses, this sector has become the largest contributor to the deterioration in air quality in urban

settlements. In Bombay, Delhi and Calcutta, on an average, vehicular emissions account for around fifty per cent of all oxides of nitrogen and about thirty percent of all particulate emissions. The major share is contributed by heavy duty diesel vehicles (trucks and buses) and by two stroke engine vehicles (scooters, motorcycles, mopeds and auto-rickshaws) (Mathur, 1989 b).

Emissions were determined by the product of per capita emissions and population for each zone in all the regions. Per capita emissions for each zone were estimated by taking a representative urban conglomeration and its travel demand. It is difficult to estimate a different set of figures for the 5% and 6% scenarios since on one hand higher GDP results in greater travel demand (passenger kilometers and tonne kilometers) while a lower population (associated with the 6% GDP scenarios) would tend to lower the travel demand. The emissions from the transport sector are presented in Table 4.12 and can be considered as representative loadings for both the scenarios.

### .3.3 Domestic non-commercial sector

In literature, deforestation has been defined in several distinct ways, e.g. transformation of primary closed forests to any other formations; loss of any kind of closed forest; and loss of forest land (Allen and Barnes, 1985; Meyers, 1980; FAO/UNEP, 1982 a & b; FAO, 1980).

It is, therefore, clear that the precise definition of deforestation must first be specified. Attributing causes for deforestation can only follow such an exercise. Take, for example, the hypothesized link between firewood use in rural areas and deforestation. If either of the first two definitions are followed, studies in the past (such as the NCAER survey in 1979) indicate that rural energy use is very **rarely** responsible for any deforestation since a large fraction of the woody biomass used is in the form of twigs. If, on the other hand, the third definition were to be followed, deforestation and rural energy use would have much closer links. The third definition incorporates a much wider definition of forests. The use of woody biomass in urban areas can more often be linked to deforestation than rural energy consumption. Surveys in cities indicate that the need for lower transportation costs leads to a better variety of woody biomass (essentially logs, but not thick enough to have timber value).

**Table 4.12. Emissions from the transport sector**

		(thousand tonne)														
		SO <sub>x</sub>			CO			NO <sub>x</sub>			TSP			HC		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
<b>North</b>																
	1990	12	1	31	299	53	1673	72	9	187	6	1	34	109	22	870
	1995	15	2	29	416	67	2212	94	10	174	8	1	42	151	28	1218
	2000	20	2	43	559	96	3568	121	11	197	10	2	69	206	42	2047
	2005	39	2	52	842	132	5288	165	13	257	15	2	104	306	69	2651
	2010	35	3	62	1223	199	8380	218	16	282	22	4	149	449	119	3941
<b>West</b>																
	1990	17	2	23	426	62	1223	103	11	137	8	1	25	155	25	636
	1995	21	2	21	580	84	1640	130	12	129	11	2	32	211	35	902
	2000	27	3	22	751	138	2418	162	17	133	14	3	47	276	61	1386
	2005	51	3	34	1104	210	3495	216	21	170	20	4	70	401	109	1757
	2010	44	5	33	1552	362	4501	277	29	152	27	7	80	570	216	2117
<b>South</b>																
	1990	1	3	26	21	100	1402	5	17	157	0	2	28	8	40	729
	1995	1	3	24	31	129	1841	7	19	145	1	2	36	11	54	1013
	2000	2	4	26	43	195	2808	9	23	155	1	4	54	16	85	1610
	2005	3	5	40	68	277	4033	13	27	196	1	5	80	25	144	2028
	2010	3	6	46	102	435	6218	18	35	210	2	9	111	38	260	2925
<b>East</b>																
	1990	12	1	24	289	23	1283	70	4	144	6	0	26	105	9	667
	1995	14	1	22	379	32	1701	85	5	134	7	1	33	138	13	937
	2000	16	1	25	464	54	2674	101	7	147	9	1	52	171	24	1533
	2005	30	1	39	659	83	3920	129	8	191	12	2	78	239	43	1971
	2010	25	2	45	887	142	6129	158	11	207	16	3	109	326	84	2883
<b>North-east</b>																
	1990			5			238			27			5			124
	1995			4			331			26			6			182
	2000			5			505			28			10			289
	2005			7			754			36			15			379
	2010			9			1214			41			22			571

1 - Zone 1, 2 - Zone 2, 3 - Zone 3

Based on the fuelwood demands presented in Table 2. (Chapter 2, Section 2.2) and sustainable yields in Table 1.14 (Chapter 1, Section 2.5.1), the approximate level pressure on forest resources is presented in Table 4.1

Table 4.13. The level of pressure on forests because of fuelwood requirements

	Degree of shortage					
	1991	1995	2000	2005	2010	
ASTERN						
Bihar	severe	severe	severe	severe	severe	
Orissa	none	none	none	none	sign.	
West Bengal	severe	severe	severe	severe	severe	
ORTHERN						
Gujarat	severe	severe	severe	severe	severe	
Haryana	severe	severe	severe	severe	severe	
Himachal Pradesh	none	none	none	sign.	sign.	
Jammu & Kashmir	surplus	surplus	none	none	none	
Punjab	severe	severe	severe	severe	severe	
Uttar Pradesh	severe	severe	severe	severe	severe	
ORTHEASTERN						
Arunachal Pradesh	surplus	surplus	surplus	surplus	surplu	s
Assam	sign.	sign.	major	major	major	
Manipur	surplus	surplus	surplus	surplus	surplu	s
Meghalaya	surplus	surplus	surplus	surplus	surplu	s
Mizoram	surplus	surplus	surplus	surplus	surplu	s
Nagaland	surplus	surplus	surplus	surplus	surplu	s
Sikkim	surplus	surplus	surplus	surplus	surplu	s
Tripura	none	none	sign.	sign	sign	
OUTHERN						
Andhra Pradesh	major	major	severe	severe	severe	
Karnataka	major	major	major	major	severe	
Kerala	severe	severe	severe	severe	severe	
Tamil Nadu	severe	severe	severe	severe	severe	
WESTERN						
Goa, Damand and Diu	sign.	none	none	none	none	
Madhya Pradesh	none	none	none	none	none	
Maharashtra	major	severe	severe	severe	severe	
Rajasthan	severe	severe	severe	severe	severe	

sign. : significant

Generalizing sustainable yield from forests (natural or man made) is difficult. Sustainable yields depend on a wide range of factors, e.g. from quality of land, the species planted, the nature of wood removal, etc. There is no conclusive average sustainable fuelwood yield. The National Commission on Agriculture (NCA) in its report found that the recorded firewood removal in the period 1965-70 was high (0.61 t/ha/y) in U.P. and the national average was 0.13



t/ha/y. It also felt that the recorded removals accounted for not more than 10 per cent of total removal, thereby implying a productivity of about 6.1 t/ha/y for U.P. and the national average of about 1.3 t/ha/y. The Advisory Board on Energy quotes a World Bank appraisal report on expected yields from some social forestry projects. The expected yields, according to this report, range from a low of 0.9 t/ha/y for 'Babul' tree plantation on average land to a high of 14.4 t/ha/y for Leucaena species planted on irrigated land along canals. Another report indicates that the present productivity is a mere 4 per cent of the potential and that with proper management, the productivity of 4-8 t/ha/y is realizable.

Clearly, no estimates of either the sustainable yield or the contribution of forest resources to the total firewood and/or wood demand, at the macro level, can be defended with much rigour. These are, at best, rough estimates and should be treated as such. The situation will remain the same under both scenarios.

#### **4.4 Carbon dioxide emissions from energy production and use**

Anthropogenic emissions are substantially increasing the atmospheric concentrations of greenhouse gases (carbon dioxide, methane, chlorofluorocarbons and nitrous oxide). The Intergovernment Panel on Climate Change (IPCC) has estimated that CO<sub>2</sub> is responsible for approximately 61% of the increases in radiative forcing due to increased concentrations of GHGs since pre-industrial times. Table 4.14 shows CO<sub>2</sub> emissions for both the scenarios.

It is estimated that total CO<sub>2</sub> emissions increase at an annual average rate of roughly 4.8 per cent per annum over the period 1990-2010. Although coal accounts for the maximum emissions in absolute terms under the BAU scenario, emissions from natural gas increase at the fastest rate. At the level of individual sectors, the power sector makes the greatest contribution to CO<sub>2</sub> emissions followed by industry.

**Table 4.14.** CO<sub>2</sub> Emissions for the BAU scenario (million tonnes)

n	Year	5% GDP growth rate			6% GDP growth rate		
		Coal	Oil	Nat. Gas	Coal	Oil	Nat. Gas
	1990	28	12	3	28	12	3
	1995	29	19	4	29	20	4
	2000	38	25	6	40	27	7
	2005	50	33	7	56	35	8
	2010	69	43	8	82	47	10
	1990	47	12	3	47	12	3
	1995	50	20	5	51	21	5
	2000	60	26	9	64	28	8
	2005	74	33	10	83	35	11
	2010	94	42	14	112	46	15
h	1990	30	9	1	30	9	1
	1995	30	15	1	31	15	2
	2000	40	19	2	44	20	3
	2005	52	24	3	61	33	3
	2010	71	31	5	89	33	5
t	1990	37	7	0	37	7	0
	1995	41	11	0	41	11	0
	2000	48	15	1	50	15	1
	2005	58	19	1	62	20	1
	2010	74	25	1	83	25	1
th-east	1990	1	1	1	1	1	1
	1995	1	2	1	1	2	1
	2000	1	2	2	1	2	3
	2005	1	3	3	1	3	4
	2010	2	4	5	1	4	6

t Gas: Natural Gas

#### 4.5 Location specific environmental impacts

#### 4.5.1 Singrauli Region

Singrauli straddles the border between the states of Madhya Pradesh and Uttar Pradesh in Central India and covers a total area of about 313 183 ha. In 1981, land use was divided among forests (35%), arable land (36%), Rihand reservoir (14%) and area not available for cultivation (15%). Since 1981, the overall land use pattern has undergone considerable changes

following large scale concentration of economic activities such as coal mining and power generation, particularly in the area around the reservoir. Coal is by far the most significant mineral of this area. The Singrauli Coalfield extends over an area of 2200 sq.km. and has an estimated coal reserves of 10850 MT as detailed below in Table 4.15.

**Table 4.15.** Coal reserves of Singrauli coalfield

(million tonnes)

Category	Upto 300 m depth	300 m - 600 m depth	Total
Proved	3801	28	3829
Indicated	1245	76	1321
Inferred	1405	4295	5700
Total	6451	4399	10850

**Source:** Environmental Study of the Singrauli Area, Synthesis Report (March 1991), NTPC.

- 4.5.1.1 Land use pattern: The land use pattern in the core industrial area is given in Table 4.16.

**Table 4.16.** Land use pattern in the core area

Land use	Area covered (ha)	Percent share
Power Plants		
Plant	1040.0	2.2
Ash dykes	4500.0	9.4
Power transmission corridor	14428.0	30.1
Sub-total	19968.0	41.7
Coal Mines		
Mining block	14905.0	31.1
Infrastructure	3319.0	6.9
Spoil dumps	732.0	1.5
Sub-Total	18956.0	39.5
Other Industrial Area	1737.0	3.8
Total	47925.0	100.0

Status of the environment in the region: Given the availability of water from the Rihand reservoir and the abundance of coal reserves, large open-pit coal mines and super-thermal power generation stations have been established in the region. This has resulted in rapid industrial development of the area. All the natural resources such as air quality, water quality (surface and groundwater), forests and natural vegetation, and agricultural land are being affected by the developmental activities. The key issues are:

- (1) Air pollution mainly in the form of dust. This is primarily due to soil erosion followed by coal mining, loading and transportation activities. Combustion of large amounts of coal in thermal power plants produces sulphur dioxide (SO<sub>2</sub>), oxides of nitrogen, fly ash etc.
- (2) Water related problems including contamination of Rihand reservoir from fly ash, huge quantities of sediments from mining area and a high concentration of iron and chloride in some of the ground water.
- (3) Loss of forest areas and agricultural lands due to acquisition of land for industrial and residential purposes.
- (4) Displacement of local population.
- (5) High growth rate of population largely due to migration from within and outside the region.

#### Development scenarios

- .1 Power generation: Under an environmental study conducted by the National Thermal Power Corporation, Government of India, two main scenarios of development (most likely and tentative) have been contemplated for power generation in the region. These are given in Table 4.17.

**Table 4.17.** Power generating capacity and coal requirement

Item	Power Capacity (MW)	Coal Requirement (MW)
Existing	6760	21.97
Most likely scenario	10510	35.35
Tentative/Ultimate capacity	18510	62.27

**Source:** Environmental Study of the Singrauli area, Synthesis Report, NTPC (March 1991)

Air pollution: The annual emission for the three scenarios are given in Table 4.18.

**Table 4.18.** Annual Emissions of Pollutants

(Thousand Tonnes)

Pollutant	Existing	Most likely scenario	Tentative/Ultimate
SO <sub>2</sub>	209	336	592
CO	6	9	16
NO <sub>x</sub>	219	352	621
SPM	6152	9898	17436
HC	3	5	9

Existing dust levels range from 40 to 60 ug/m<sup>3</sup> in the wet season. However, in the dry season the levels can range between 200 and 400 ug/m<sup>3</sup>. SO<sub>x</sub> levels are between 40 and 60 ug/m<sup>3</sup> while NO<sub>x</sub> is below 40 ug/m<sup>3</sup>.

Because of the higher ash content in Singrauli coal, large quantities of fly ash are produced. ESPs can reduce fly ash emissions substantially. Accounting for bottom ash removed from boilers and fly ash collected from ESPs, approximately 6 MT have to be disposed every year. This quantity increases to about 11 MT in the most likely scenario and to 19.5 MT under the tentative/ultimate scenario. The estimated land area required for the ash ponds is given in Table 4.19.

**Table 4.19.** Estimated land area required for ashponds in the Singrauli region

	Existing	Most likely	Tentative/Ultimate
Ash produced (MT)	6.05	10.9	19.5
Ash pond area (ha)	836.5	1586.5	3186.5

**Source:** Environmental study of Singrauli area, Synthesis Report NTPC, Govt. of India (March, 1991)

### Coal mining

Production: For operational purposes, the working section of Singrauli coalfield has been divided into 12 mining blocks. Of these, 9 are working mines and 3 are under preparation. In 1990-91, the production was about 25 MT. The tentative/ultimate capacity is assessed at 65 MT and the most likely capacity at about 52 MT per annum.

Land degradation: The total land required for mining operations is about 19,000 ha for all projects of which nearly 9500 ha (50%) is under forests. Out of this, 6000 ha are under coal mining and related activities.

Compensatory afforestation: Following the introduction of the Forest Conservation Act, 1980, a compensatory afforestation scheme is to be prepared by the coal company with the help of the forest department and the State Government. These schemes envisage afforestation of equivalent area of revenue land or non-forest land or twice the area in degraded land provided by the State Government.

Dust: Dust is a severe problem for the Singrauli area. Studies conducted have indicated that the major source of dust is soil erosion followed by the coal mining, loading and transportation activities. The range of dust level is given in Table 4.20.

**Table 4.20.** Range of dust levels

Zone	SPM ( $\mu\text{g}/\text{m}^3$ )	Total dust $\mu\text{g}/\text{m}^3$	Sedimentable particles ( $\text{g}/\text{m}^2$ )
Vicinity of coal mines	200-700	500-1200	20 to 150
Vicinity of cement plant	250-400	800-2000	15 to 70
Industrial area with road traffic	100-300	300-1100	5 to 30

Source: Environmental Study of Singrauli Area, Synthesis Report,  
NTPC, Govt. of India (March 1991)

SO<sub>x</sub>: Values are currently ranging between 60 to 75  $\mu\text{g}/\text{m}^3$  in the vicinity of the coal mines. These levels are expected to be below ambient standards for the most likely scenario. However, the levels will be critical for the ultimate scenario.

NO<sub>x</sub>: Levels in the coal mine area are currently ranging from 80 to 120  $\mu\text{g}/\text{m}^3$ . Under the most likely scenario the levels are expected to be critical and will far exceed standards under the ultimate scenario. The operation of engines are the major source.

Agricultural land: The acceleration of industrial activities in the region has increased the competition for land for industrial vis-a-vis agricultural use, particularly in the core area. This has resulted in decrease of agricultural land, especially in the Waidhan plain, where the most fertile land is located. The industrial activity has

also resulted in displacement of local people.

Socio economic factors: Between 1971 and 1981, the population in the region registered an average annual compound growth rate of 5.59 per cent. The growth rate in the core area around the reservoir has been very high. This is mainly due to migration both from within and outside the region, largely due to increased industrial activity. Details are given in Table 4.21. Currently, one-third of the population is made up of migrants.

**Table 4.21.** Growth of population in the Singrauli Region, 1971-2001

	1971	1981	1991*	2001*	1991-2001 % change	Annual compound
Core Area	74,641	141,929	450,606	1,046,217	132	12.25
Non-core area	159,677	205,651	245,723	348,739	41	1.80
Singrauli region	234,318	347,580	696,329	1,394,916	100	7.20

\*: estimated

#### 4.5.2 Delhi

Until recently, energy planning in India was done with little concern for environmental effects of energy production, conversion, transportation and utilization. However, the implications of one or more of these steps in the energy chain may be particularly significant in areas of concentrated population such as large metropolitan cities. The situation of Delhi, with a present population of over 8 million, is typical of these concerns.

Over the past two decades, Delhi has witnessed rapid industrialization and the consequent influx of population from neighbouring states. Undoubtedly, these activities are signs of economic development of the region but there are adverse environment related problems associated with it.

Among the environmental effects that may be considered is the impact of air pollution on human health. Delhi records 12 times the national average for respiratory ailments mainly due to unchecked pollution (National Capital Region Planning Board, 1987). The ambient air quality data show that the annual and 24-hourly mean values for SO<sub>2</sub> and NO<sub>x</sub> did not

exceed the stipulated standards during 1989 whereas the annual mean values for TSP exceeded  $200 \text{ ug m}^{-3}$  at all the six monitoring stations. The annual minimum, mean and maximum values observed at Shahzada Bagh (where the levels are maximum) are 3, 9.9, 46.7 for  $\text{SO}_2$ ; 4.5, 21.2, 78.2 for  $\text{NO}_2$ ; 165, 510, 1932 for TSP respectively.

The three major polluting sectors are power, transport and industry. At present, there are four thermal power stations in Delhi having a total generating capacity of 1320 MW, of

which 180 MW is run on gas. These thermal power stations consume about 3.7 MT of coal per year and 50,000 tonnes of furnace oil. Moreover, an additional capacity of 210 MW is proposed for future.

With increasing population, the transportation needs are growing rapidly. Vehicle population in Delhi has reached 1.7 million and every year 0.17 million vehicles (500 vehicles a day) are being added to it. The growth of motor vehicles was around 20% per annum between 1970-71 and 1986-87. Of all the vehicles, two-wheelers have registered a maximum growth of 12.7% per annum. Overall growth of personal vehicles is around 10.5% as compared to public transport vehicles such as taxis and autorickshaws (three-wheelers), which have registered a growth rate of 3.6% and 6.8% respectively. This has resulted in a major change in the modal mix for Delhi. There has been a marked shift away from the public modes of transport to the private modes. The trend has led to congestion, thereby reducing the speed of vehicular movement and their fuel efficiencies. This has resulted in high pollution levels, and a steady deterioration in the quality of air. As no major policy intervention to reduce the growth has been initiated, the transport situation of Delhi might deteriorate further in the future. The two major fuels used for the propulsion of vehicles are motor spirit and high speed diesel oil. The consumption of these fuels in the city during 1988-89 was 572,000 tonnes (High Speed Diesel) and 293,000 tonnes (Motor Spirit).

Exhausts from transport vehicles are characterized by large amounts of  $\text{CO}$ ,  $\text{NO}_x$ , TSP as well as relatively smaller amounts of  $\text{SO}_2$ . In the absence of any control of emissions from automobile sources, exhaust gases contribute significantly to urban air pollution. The atmospheric pollution problem is further aggravated because the atmospheric conditions do not favour the dilution of pollutants most of the year around.

Similar impacts can be attributed to the utilization of



petroleum products and traditional fuels in the small scale manufacturing industries clustered in Okhla, Naraina Vihar and other industrial estates.

To quantitatively assess the severity of the problem, annual emissions of four pollutants---SO<sub>2</sub>, CO, NO<sub>x</sub> and TSP---are estimated for the period 1989-90 and are presented in Table 4.22.

It can be seen that total emission of CO was the highest (1,921,000 tonnes), followed by TSP (154,040 tonnes), NO<sub>x</sub> (132,670 tonnes) and SO<sub>2</sub> (50,400 tonnes) during 1989/90.

CO emissions are maximum from transport sector (87%), followed by industry (12.5%). Particulate emissions are maximum from industries (69%), followed by power (28%) and transport (3%). Maximum NO<sub>x</sub> emission is from the transport sector (65%), followed by power (29%) and industry (6%). Finally, the major source of SO<sub>2</sub> emissions is the power sector which contributes nearly 74% of the total, followed by industry (13%) and transport (12%). It can therefore be inferred that transport sector is largely responsible for CO and NO<sub>x</sub> emissions, whereas industry is mainly responsible for TSP and SO<sub>2</sub> emissions.

The projected emissions levels in the target year as given in Table 4.22 shows that CO and NO<sub>x</sub> levels are likely to grow rapidly vis-a-vis other pollutants. This is mainly due to the rapid expansion of the transport sector. Thus, the strategy to reduce emission levels in Delhi, should target the transport sector as a priority area. The other area which needs attention is the control of TSP (which is at present far exceeding the standard). Since it is mandatory to install ESPs for power plants, it is the industrial sector where control technologies need to be focused.

**Table 4.22.** Emission of Pollutants by Energy Consumption in Delhi : 1989-2010 (thousand tonnes)

Sectors	SO <sub>2</sub>		CO		NO <sub>x</sub>		TSP	
	1989	2010	1989	2010	1989	2010	1989	2010
Power	37.34	46.13	0.97	1.2	38.25	39.5	43	52
Transport	6.39	23.60	167.02	837	88.04	150	5	15
Industry	6.67	6.67	24.18	24.18	6.38	6.63	107	106
Total	50.40	76.40	192.17	862.38	132.67	196.13	154	173

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**Measures to combat environmental impact**

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**Introduction**

A move towards rational and environmentally-responsible energy use patterns and practices would require the creation of appropriate incentives consisting of appropriate governmental policy interventions. While these interventions would rely on policy instruments such as fiscal, tariff, and administered price regimes, there may be a need to retain regulatory instruments which are more direct\*.

The choice of policies/instruments has to be viewed in the context of the existing political scenario, legal structure, and administrative capacity besides, theoretical and empirical considerations of their likely effects.

The Indian economy is characterized by private, public (and to some extent co-operative) forms of ownership in the industrial and service sectors, and largely private ownership by small landholders in agriculture. The public sector dominates several industries in the share in total output and capital investment, e.g. commercial energy, steel, petrochemicals, non-ferrous metals, etc. as well as several service sectors, e.g. railways, air transport, banking, and insurance. The extent of such dominance is often such that public sector firms have considerable influence over the price of their outputs. In addition, public sector firms do

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\* This is because some of the relevant markets may be too thin, or otherwise characterized by pervasive failures. A fundamental distinction is made in the environmental economics literature between market-based (or "incentive based") and fiat (or "command and control") instruments for pollution regulation. This latter category of policy instruments may include quantity restrictions (including those on emissions), and mandated technologies or technical performance standards (for example energy conversion or end-use efficiencies), besides others. The received wisdom of neo-classical economics is that, in general, market-based instruments ensure cost minimization for any given environmental standard whereas fiat instruments cannot.

not (in all likelihood), adhere to the neo-classical paradigm of profit maximization (or even cost minimization for a given level of output), and accordingly, their input and output choices are often found to be insensitive to market (price) incentives and remain largely unaffected by direct regulatory measures. Moving towards greater privatisation of industry thus seems not only desirable but is probably the only feasible solution to increasing total factor productivity, including energy.

However, the private sector as a whole is characterized by an appreciable proportion of enterprises belonging to the "unorganized" sector, which are neither incorporated, nor maintain detailed accounts, nor are subject to professional audit. One result of this is widespread non-compliance with direct and indirect taxation regimes, making these instruments only partly effective. As bringing this sector under effective control of the administrative machinery is a near impossible task given its size and dispersion, market based instruments appear to be the desirable means of promoting energy efficiency and environmental consciousness.

With the principal public policy focus on increasing GDP growth rates and per capita incomes, and the abysmally low per capita energy consumption levels, actual reductions in energy use cannot be contemplated - either in aggregate or in per capita terms. However, the energy intensity of the economy can be improved while promoting the twin objectives of growth and enhancing environmental quality by adopting the following broad measures :

- (1) Strengthening the environmental policy and reformulating related policies to ensure a sustainable development path while keeping in mind national objectives of growth.
- (2) Encouraging/promoting more efficient use of energy.
- (3) Promoting the development and use of more environmentally friendly energy forms.

## **5.2 Strengthening and reformulation of policies**

### **5.2.1 Environmental policy**

The environmental policy in the country today is by and large restricted to requiring the industry to submit an assessments of environmental impact of various projects before they are undertaken. While emission standards have also been specified for particular pollutants, there is insufficient monitoring and implementation of these standards. The environmental policy needs to be strengthened through

stringent legislation to limit emissions from various activities, followed by proper monitoring and control. The imposition of taxes (penalties) on emissions of pollutants (if exceeding the stipulated limits) would convey to consumers the environmental costs of consuming particular types of products, as well as encourage a shift towards more environmentally benign energy forms and final products.

#### 5.2.2 Energy policy

The first and foremost requirement is for the Government of India to recognize that the various forms of energy need to be viewed holistically. Integrated energy planning is essential for ensuring an optimal allocation of resources. The fragmented nature of energy planning today brings narrow sectoral interests to the fore and does not take into account the inter-fuel substitution possibilities that exist in the economy, resulting in a sub-optimal production mix. As a result, each energy department concentrates its efforts towards increasing supply irrespective of availability of alternative energy forms and fuel substitution possibilities. Planning for energy demand shifts and management is more or less non-existent. To the contrary, any private efforts to improve efficiency through the use of co-generating systems are dampened by the requirement of obtaining permission from the respective state electricity boards.

#### 5.2.3 Investment policy

Due to the fragmented nature of planning and lack of an overall perspective, investment decisions for the energy sector tend to be based on short-term targets and benefits. For instance, despite increasing transmission and distribution losses and poor performance of existing power plants, the focus of investments in this sector has been on increasing generating capacity. Similarly, despite the fact that natural gas is a convenient, efficient and environmentally benign fuel to use, 30-40% of the gas produced continues to be flared annually - a totally non-productive and polluting activity. In addition, the abundant renewable energy resources of the country have been given a very low priority with less than 1% of total energy outlay earmarked for this sector.

The procedural red tape in getting clearances for various investment projects results in delays and cost overruns - particularly in public sector projects such as those of

energy. This necessitates the use of petroleum products as swing fuels. Combined with operational inefficiencies of the public sector, this has resulted in increasing the incremental capital-output ratios in the energy sector. Furthermore, as these high costs are not reflected in the price structure, particularly of coal and electricity, the financial health of these organisations is poor.

#### 5.2.4 Pricing policy

It is widely recognized that in many countries, inefficient energy use is a consequence of the failure of energy prices to reflect the full social costs. This may be on account of "irrational" administered pricing regimes (in the sense of prices being politically determined from considerations other than economic efficiency), or the failure of markets to reflect environmental externalities, or being non-competitive, or due to direct and indirect subsidies on energy use. Administered prices for commercial energy in India do not, in general, reflect the principle of marginal (or even average) cost pricing. Further, the relative prices often convey signals that run counter to desired directions of inter-fuel substitution.

A rational integrated energy pricing structure reflecting the full costs of environmental damage could achieve the objectives of promoting energy and environmental use efficiencies and fuel substitution in desired directions while keeping in mind the overall social objectives.

In addition, the introduction of seasonal and time-of-use (TOU) prices would encourage consumers to manage electricity demands better. Under the tariff structure based on TOU electricity consumed during peak hours is charged at a higher rate than during off-peak hours. Thus it is necessary to determine the quantities consumed in these periods. This requires special meters which are very expensive and this has been a major constraint in introducing TOU pricing. The utilities in India may, however, initiate TOU tariffs for industrial consumers on an experimental basis using a simple control circuit along with the conventional meters. A simple time switch alternatively switches on and off the two mechanical devices during different time periods - peak and off-peak, thereby approximating TOU metering at much lower costs than specialized TOU meters.

An example of irrational pricing hampering energy efficiency is found in the coal sector. A recent study (TERI, 1991) notes certain anomalies in the pricing of coal the removal of which will tend to improve the efficiency with

which the fuel is consumed. It was found that in some cases inferior grades of coal are priced higher than superior grades per unit of heat delivered. Thus instead of being compensated for using an inferior grade the consumer is penalized. Correcting this irrationality would tend to improve the efficiency of coal use, since the saving from the 'corrected' price may be used for efficiency enhancing investments. The higher price for those consuming superior grades would induce them to use it more efficiently.

An anomaly exists in the price received by the producers as well. A uniform price is paid to them for coal within the same grade even though within this grade coals vary in terms of heat values. As a result there is no incentive for the producers to supply coals with higher heat values covered in that grade since this would involve extra work without commensurate return. Higher prices for better quality coal would increase its supply. An improvement in coal quality translates into improved efficiency of use.

#### 5.2.5 Fiscal policy

The category of fiscal incentives for greater energy efficiency may include indirect taxes on energy sources as well as taxing inefficient use of energy, such as private modes of transportation, while subsidizing more efficient uses, such as mass transportation. Further, instruments such as carbon taxes and tradeable permits may also be operated by modification of the existing fiscal regimes. Other fiscal strategies, for example indirect taxation of energy intensive sectors such as steel or aluminium manufacture, may have the effect of significantly reducing overall energy consumption in the economy, by promoting factor or material substitution. In addition, energy efficient industrial units could be given incentives in the form of tax reliefs. However, the structure of federal and state taxes/subsidies, which are governed by political motivations, distort the present regime substantially. This leads to heavy losses to the economy not only in energy use but also in terms of financial resources.

The Government of India has introduced some financial incentives in order to encourage industry to adopt energy saving devices. A limited number of industries have availed of and benefited from these schemes. The widespread adoption of energy-efficient technologies also requires that certain lacunae and inconsistencies in the existing regime be removed and their coverage be broadened.

The incentives offered at present include :

- a) a 100% write-off facility for energy saving devices in the first year itself
- b) excise duty concessions
- c) concessions on import duties

There are, however, some conflicts between these incentives which erode their effectiveness. For instance, vapour absorption refrigeration systems are included on the list for the 100% write-off facility but these do not qualify for customs duty concessions. The high rates of import duties makes it unprofitable to employ them, thereby rendering the write-off facility unusable.

There are some policies that discourage indigenous production of energy saving devices. The import duties on alloy steel tubes (which are used to manufacture recuperators) vary from 110-330% . However, duty on recuperators themselves is around 85% and are therefore cheaper to import. This duty structure needs to be rationalized. In addition the Government may provide incentives to initiate manufacturing ventures by liberalising the import of technology on the one hand and allowing collaborations with international firms on the other.

Apart from ironing out inconsistencies in its fiscal structure, the Government also needs to expand the coverage of its existing policies. Excise duty relief is, so far applicable only to equipment dealing with solar energy, wind energy, ocean energy, municipal waste and bio-gas. However, it also ought to include equipment that promotes commercial energy conservation. In another instance, a PCRA (Petroleum Conservation Research Association) scheme offers a subsidy for replacing old oil fired boilers by newer oil/coal fired ones. The coverage of this subsidy should also be expanded to cover old coal fired boilers which can be replaced by more efficient ones.

Industrial units which require substantial capital investment for their own generation of power should be given tax incentives by the Government. Such incentives can take the form of depreciation benefits. Considering the obvious advantages of co-generation to the nation, the Government should remove the currently applicable self-generation tax, wherever applicable. Additionally, in order to realise co-generation investment and make it attractive to industry, the State Governments should enact legislation which would require the state electricity boards to purchase surplus electricity from private co-generation and provide back-up power when needed. The states of Tamil Nadu, Gujarat and

Maharashtra have already taken measures to this effect, with the state utilities standing ready to buy surplus co-generated power at avoided cost.

On points where the quantity of waste heat exceeds the plant's thermal requirements, installation of electric generation using condensing turbines will conserve energy. Although this is not co-generation, such installations should be encouraged and they should enjoy the same benefits as those applicable to co-generation.

#### 5.2.6 Credit policy

In addition to the above mentioned fiscal incentives, and in order to make the returns on investment on energy conservation technologies attractive, the Government may consider options for arranging concessional loans through banks and other financial institutions. According to a survey conducted by the National Council for Applied Economic Research (NCAER, 1989), the most important factor which inhibited the adoption of energy saving devices was the lack of funds. A substantial number of the units surveyed (108 of 196) considered a soft loan facility as their first or second preference. Therefore, the Government should create a National Fund which may be administered by one of the development banks. Such a Fund may be used for obtaining credit for procuring energy saving technologies. Disbursement of funds can be made on soft terms and delinked from the usual yardstick of debt-equity ratio.

The terms of these loans could be even softer for the first few firms. These units indirectly serve the vital infantile field and may induce strong demonstration effects. Industries which have backward linkages with such units may reap vast benefits in future. The technologies may also have spin-off effects in the form of technology improvements emerging from initial experiences.

It should be borne in mind, however, that the aforementioned fiscal and credit reforms may only be necessary for greater energy conservation, and may not be sufficient. In other words, the Government may have to back such incentives through the establishment of complementary institutional arrangements. These include the setting up of a Central Government institution that implements all energy conservation policy and continuously monitors and evaluates the programme. An important function of such an institution will be the dissemination of information regarding energy conservation technologies as also demonstrating their worth.



For this, the Government can also encourage private sector firms that undertake the implementation of energy conservation measures on a turn-key basis.

#### 5.2.7 Industrial policy

The Indian economy has largely been a controlled economy and most industrial expansion programmes have to be licensed by the Government of India. While a certain amount of decontrol has been introduced in the recent past, the industrial policy could still influence, to a large extent, the types of industries and technologies/ processes that are to be set up in the country. A first step in promoting efficient use of various resource inputs is to introduce fair competition. To ensure complete fairness, the cost of energy to industry should also be rationalised -- Indian industry pays a very high price for the energy it consumes as compared to those in other countries. In the formulation of the industrial policy, due regard should be given to the availability of energy and the costs of supplying these energy forms.

#### 5.2.8 Transport policy

Transportation infrastructure planning should go hand in hand with regional development planning and urban development planning. Adequate, reliable and efficient mass transportation capacity should be ensured to discourage the use of private modes of transportation. Unfortunately, in the eighties, the GOI actually encouraged the use of private means of transport through the introduction of low-priced cars and large scale licensing of two-wheeler production capacity.

Inadequate investments in the railways have led to an increasing dependence on the more energy intensive forms of road transportation. Major R&D efforts are called for to improve efficiencies of different modes of transport and to switch to alternative energy forms such as CNG both in road as well as rail transport.

#### 5.2.9 Trade policy

A major focus of trade policy should be to facilitate the creation of infrastructure and regional markets for energy resources such as hydroelectricity and natural gas which are available in abundance in some of the neighbouring countries. The constraints on such developments are well recognised and include the issues of security of pipelines or transmission lines from hostile environment, the question of energy and infrastructure pricing in monopoly-monopsony market

structures, the denomination of an appropriate currency for transactions, devising adjudication mechanisms for disputes, and adopting convergent technical standards and practices.

#### 5.2.10 Agricultural policy

As mentioned earlier, energy intensity of the agricultural sector is growing partly because of the need to increase productivity and partly due to the inefficient utilization of energy. While efficiency improvements can be affected through a proper pricing policy, agricultural policy can also play a significant role in ensuring, through the procurement price structure, a rational cropping pattern in various regions of the country which is suited to the available local resources.

Finally, there is an extensive system of land records, enforcement of land ownership and tenurial rights, and forestry records and management. The significance of the last aspect lies in that it may make feasible the adoption of regulatory regimes for CO<sub>2</sub> emissions, which treat forestry plantations as an abatement industry.

### 5.3 **Potential for more efficient use of energy and inter-fuel substitution**

Energy efficiency improvements can be classified as efficiency improvements in production, conversion, transportation and end-use efficiency improvements. From the environmental point of view, the following measures are significant: (i) increase in the conversion efficiencies of coal-based thermal power plants; (ii) washing of coal which has implications for both transportation and end-use energy demands; (iii) reduction of transmission and distribution losses for electricity; and (iv) efficiency improvements in each of the consuming sectors, viz. industry, transport, agriculture, domestic and the commercial sectors.

#### 5.3.1 Efficiency improvements in thermal power generation

Thermal (coal-based) power plants in India are consuming a larger quantity of energy per kWh of power generated than the established norms for a number of reasons. These include (i) inferior quality of coal supplied to power plants which results in inefficient operation of boilers; (ii) inappropriate use of thermal power plants as peaking plants due to short-term investment priorities; (iii) a larger amount of oil being consumed per unit of power generated due

to both the above factors. Overall thermal efficiency of power plants can be improved by a more optimal use of existing power generating capacity and by removing the imbalance that exists in the power utilities with regard to peak and off-peak generating capacities. Technological changes/retrofitting of components in existing thermal power stations can also lead to increased energy efficiency.

5.3.2 Reduction in transmission and distribution (T&D) losses  
T&D losses in the country have been increasing over time and it has been estimated that these losses can be brought down from the present level of approximately 23 per cent to at least 15 per cent.

5.3.3 Washing of non-coking coal  
Indian coals on an average contain 35 per cent of ash. The washing of non-coking coals is desirable as (i) the consumer is provided with low ash non-coking coal leading to a reduction in emissions of pollutants at least in the industrial sector; (ii) the middlings that are produced in the washing process can be used by industry or power utilities leading to an overall improvement in energy utilisation efficiency; (iii) the washing of coal reduces energy consumption indirectly in the economy as a whole because a lower amount of ash is transported.

5.3.4 Efficiency improvements and fuel substitution in the demand sectors

5.3.4.1 Industrial sector: The industrial sector accounts for the major part of commercial energy consumption in the country. Surveys carried out by various organisations reveal that the conservation potential in the industrial sector (through good housekeeping measures in the short term and through process modification, modernisation, etc. in the long term) is close to 20 per cent. Industries could contribute to a lower electricity intensity in the economy through measures such as efficiency improvements of motors, refrigeration equipment and lighting systems; demand management to smoothen the load curve by rescheduling of operations and by ensuring a proper matching of various pieces of equipment used in the system as a whole. On the thermal energy side, industry could contribute by improving efficiencies of boilers and furnaces, better heat transfer, proper insulation, waste heat recovery and through co-generation to the extent possible. Boiler efficiency levels in the country vary from 45 to 80 per cent,

revealing a significant scope for thermal energy conservation. The industrial sector also has a significant potential for reducing overall energy intensity through process and technological changes. For example, the use of naphtha as a feedstock in the fertilizer and petrochemical sectors could be substituted by the use of natural gas. Similarly for some of the low process heat demands of industry, renewable solar thermal options can be considered.

3.4.2 Transport sector: Surface transport forms a major part of transportation in the Indian economy. Railways and roadways together account for close to 90 per cent of total transportation. Unfortunately, over the last few years, there has been an increasing trend towards meeting a major share of transportation energy requirements through road-based movements rather than the more economical and efficient railway system.

Strategies to reduce the increasing energy intensity of (surface) transportation in India could center on the following steps:

- (1) A shift in both commuting and long distance passenger travel from personalized to mass transport.
- (2) Within the mass passenger transport subsector, a shift from road to rail transport.
- (3) Similarly, in the case of long distance freight movement, a shift from road to rail transport.
- (4) Introduction of more energy efficient vehicles for passenger and freight movements.
- (5) Electrification of railway routes to the extent that is economically desirable.
- (6) Widening and improvements in the telecommunication network leading to reduced transportation energy demands.

It is generally believed that the increasing use of personalized modes for commuting is because of inadequate public investment in mass transport, i.e., buses and suburban/metro rail. Budgetary constraints lie at the root of inadequate investment in mass transport, including long distance rail. However, since personalized transport is more energy and capital intensive than mass transport, the problem is not one of inadequate capital investment in transportation as a whole.

Some policies which may motivate shifts to mass transport systems can be identified. These are:

- (1) Institutional changes to facilitate the participation of private operators in mass transport.
- (2) Ensuring that the private transportation markets are competitive. This would require complete

deregulation of routes, fare structures, and vehicle design features (except for safety and pollution regulation), and a shift in public investment patterns from road transport fleets to long term fixed transport infrastructure, i.e., the roads network.

(3) Since the sharing of railway infrastructure by numerous operators is still technically difficult, the railway network would need to remain wholly in the public sector in the foreseeable future. There would thus remain the need to locate public budgetary resources for increased investment in railways.

5.3.4.3 Household and commercial/service sectors: The main end-uses for which energy is required in these sectors include cooking, lighting and heating systems. In the household sector, most rural energy demands are met through the use of biomass fuels. Urban energy demands are catered to by petroleum products and electricity. It is highly unlikely that the dependence on biomass fuels in the rural sector will reduce significantly in the coming few decades. Therefore, more attention needs to be focused on developing appropriate technologies for more efficient utilisation of biomass resources. These measures can include improvement in utilisation efficiencies of devices such as cookstoves as well as improvements in the conversion efficiency of biomass through technologies such as biogas plant and gasifiers.

In the urban household sector conservation potential exists in both electrical and non-electrical energy uses. Non-electrical energy forms mainly comprise LPG and kerosene which have a small conservation potential. However, a significant potential exists in improving the efficiency of electrical devices such as lighting systems, refrigerators, air-conditioners and water heating systems.

In addition to a rational pricing structure, legislative measures may also have to be resorted to for ensuring minimum performance standards of these devices. The commercial sector has very similar energy needs as the residential sector and similar measures would be effective in promoting energy efficiency in this sector.

At present the electricity tariffs for the household sector are based on a block tariff structure, with the rates being higher for the higher consumption blocks. In this way the larger consumption blocks subsidise the smaller consumers. While maintaining this structure the tariffs need to be raised by building in a component that reflects the contribution of the sector to the peak load.

The contribution to the peak load which is mainly due to lighting can also be reduced. This may be achieved by encouraging the use of fluorescent tubes in place of

incandescent lamps which are mostly employed in the household sector. The government can encourage this shift through a program whereby it bears the installation costs of the fluorescent tubes which consume only about a fifth of the electricity consumed by incandescents per lumen hour. The households would, however, continue paying a bill which approximates that which they would have paid in the absence of the programme, though the actual bill would now be lower. The difference between the true bill and that actually paid can be appropriated by the government in order to recover the installation costs. Once the costs are recovered, the benefit of the lower bill can be passed on to the consumer.

5.3.4.4 Agricultural sector: The principal commercial energy inputs in agriculture are diesel and electricity. The dominant energy source is, however, electricity. Conventionally, this is explained by the fact that several public electric utilities charge a flat tariff based on the horsepower of agricultural pump-sets, and not on metered consumption. Further, the electricity tariff rates in agriculture are extremely low, and yield no more than a few percent of the LRMC of delivered power as revenue to the utilities. This fact is also believed to have contributed appreciably to increased energy intensity of agriculture because of wasteful electricity use.

The key to improving energy efficiency in agriculture is the adoption of an electricity tariff structure which would create incentives for less wasteful use of electricity, and rectification of technical deficiencies in existing pumping systems.

In addition, irrigation practices in the country are not geared towards an efficient utilisation of resources, either energy or water. The general practice is to flood the area to be irrigated. Introduction of sprinkler and drip irrigation systems could contribute significantly to an efficient utilisation of resources.

Efficiency improvements in diesel consumption could also be effected through a proper land utilisation policy. The fragmented nature of land-holdings today is not very conducive to efficient operation of tractors.

#### 5.4 **Potential for the increased use of renewable energy**

While Renewable Energy Technologies (RETs) could come to play a significant role in reducing adverse environmental impacts, it is expected that only small and mini hydel plants and wind electric generation in the grid connected mode are likely to

play a significant role by 2010. Photovoltaic systems have so far been limited to small applications, as the technology is still not economical for large scale power generation in grid connected or autonomous modes. Its use in future will be limited to autonomous, small and remote applications and the overall impact on the power sector will be negligible.

#### 5.4.1 Wind electric generation in grid connected mode

Based on the findings of a study to assess the cost and reliability of wind electric generators at different levels of penetration of wind farms in the power system of the Tamil Nadu Electricity Board (TNEB), it can be said that the technically realisable potential for windfarms in India can be computed on the basis of a 35% level of penetration. This potential is very large and in spite of special efforts, the actual installations are likely to be much lower than these figures.

Constraints: The major constraints to installing such wind farms are related to the availability of funds, logistics and the world wind turbine turnover capacity. These are discussed as follows:

Funds: The capital cost of windfarms at present is about US\$ 1500/kW, net of customs duty of about 40%. The cost of indigenously produced wind electric generators is expected to be in the range of US\$1667/kW. It is estimated that the budgetary requirements to meet the windfarms potential at 2010 is US\$ 73 billion for the 5% GDP growth scenario and US\$ 78 billion for the 6% growth in GDP.

Logistics: Identification of sites, land availability, modifications in existing grid and actual execution of the projects are the major factors to be considered. Earlier studies have shown that the land and wind resource availability are not the major constraints. However, lack of experienced and adequate manpower for preparation of specific project details would be a bottleneck.

Annual production capacity: Wind turbines are not domestically produced at present. Also, the world production capacity would have to cater to the increasing demand from Europe, USA and other parts of the world. In Europe itself, a potential of 100,000 MW of windfarms has been identified to be met over the next 40 years or so. The highest turnover from the world wind turbine industry in the last decade has been of about 500 MW. The production capacity is likely to increase with an increase in demand but this increase again is limited and time dependent.

#### 4.2 Strategies for increased grid connected windfarms

It has been established that windfarms connected to the grid not only reduce the fuel consumption but also offer some firm power at the time of peak demand. Grid connected windfarms can be promoted by a two-pronged strategy: (i) modifying the conventional power system to accept more energy from windfarms; and (ii) promoting indigenous R&D and production of wind turbines.

In a study conducted on Tamil Nadu power system, it was observed that increased capacity of pumped hydro units (acting as energy storage facilities) in the system can substantially increase the utilisation of energy from windfarms. The pumped hydro option makes it possible to absorb the load demand and smoothen wind fluctuations effectively. As the generating capacity in India is still growing, it is easier to plan the system expansion keeping in view the possibility of a large penetration of windfarms.

The private sector is already being encouraged to participate in windfarming by allowing 100% depreciation in the first year and wheeling of energy generated to the industry's plants. In Tamil Nadu a wind energy cell has been established which facilitates the project implementation for the industries. This, however, has not been done in Gujarat and Maharashtra. Large installations of windfarms will require an approach similar to that followed by the TNEB.

#### 4.3 Strategies for increased small hydro utilisation

Small hydro is perceived to be both unreliable and a high cost option among those responsible for decision making in the Indian energy sector. These two factors have led to doubts about the possible role of small hydro in the Indian energy system. However, the reliability of the small hydro system can be substantially increased through innovative and inter-linked design of small hydro facilities. A recent World Bank survey of the designs of small hydro facilities reveals the possibility of bringing down the unit cost of small hydro plants to one-third of the current costs (which are in the range of Rs 25,000-30,000/kW) by a combination of design modification and standardization of equipment.

The initial batch of small hydro schemes in India were conceived, designed and executed as scaled down versions of large conventional hydro installations. As a result of this there are numerous redundancies in the designs for the key features such as the layouts for the civil works, the facilities incorporated into the powerhouse structure, the



selection of turbine-generator equipment, and the specification of the electrical switching and protection system.

There are other measures which can result in further improvement but will require a longer time frame to implement. The design of small-hydel projects on a river basin basis on the principle of cascade development, like the Chinese small-hydel programme, can be a major factor in increasing the potential and the success of the Indian programme. In planning small hydel projects for small river basins, the emphasis should be placed on evolving designs to take advantage of the topography and to arrange the hydropower structure such that the headwork (or the intake) of one station follows closely the tailrace (open canal for tail water) of the other. The upstream regulating reservoirs can then be designed so that the cascade process raises the dependable output of the whole basin system. Such cascade systems, which can be as much as 10-20 MW, can then be integrated to form a local grid. These local grids, in turn, may be connected to a regional grid. Small hydro developed in this fashion can result in rural electrification that is fundamentally different from that of today: electrification will not simply be the extension of the large grid systems, but rather through the development and gradual inter-linking of many small, but growing, local grids. This can have a profound impact on the way in which rural electrification is visualised and implemented.

The standardization of the hydro-electrical equipment (water turbine-generator combinations) through establishing technical specification and the consequent improvement in the quality of manufacture and reduction in unit costs by enabling specialized production in batches is another measure which can go a long way in making implementation of small-hydel projects reliable and quicker. This is likely to have another very favourable spin-off. China is a good example. Measures to standardize designs of the equipment for small-hydel stations in China started in 1978. The result of this ongoing and evolving exercise is the stipulations for 4 types of turbines, 8 runner series and 32 product varieties. About 85% of all the components now have standardised designs making the production process economical and the components reliable. The standardization process has resulted in products in the capacity range of 500-10,000 kW suitable for water heads of 3-450 m. By 1989, the estimated number of hydro-electrical manufacturers has touched 100 and the annual production capacity exceeded 1000 MW.

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**Alternative energy development strategies**

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**6.1 Introduction**

As evident from chapters 3 & 4, the business-as-usual strategy of development will result in significant energy shortages -- both for the 5% and 6% growth scenarios. These shortages and adverse environmental impacts can be mitigated by adopting the following two strategies:

(1) A concerted effort towards improving the efficiency of energy production, conversion and use; management of energy demand and encouraging technology/process changes;

(2) Moving towards more environmentally benign energy forms which may be more efficient to use (for instance, natural gas) or renewable in nature (such as wind energy).

Both these strategies have been designed to comprise mutually exclusive measures so that a combination strategy comprising of both energy conservation and alternative energy measures can be readily evaluated.

**6.2 Strategy I : Energy efficiency improvements and conservation**

The need for energy conservation from the point of view of environment has been highlighted in chapter 5. Energy conservation is mandatory not only for such reasons, but also because of its direct implications on the availability of energy to a larger section of the population and foreign exchange outflows. This section analyses specific energy conservation measures that can be implemented, both on the demand and supply fronts, in the next 20 years and estimates the investment requirements of doing so.

**6.2.1 Measures on the demand side**

**6.2.1.1 Industrial sector:** Energy conservation measures have been analysed for three types of industries. The assumptions made for this sector based on discussions with industry experts are outlined below.

(a) Steel: Indian integrated steel plants tend to consume nearly 60% more energy than their counterparts abroad.

A major part of energy consumption in the steel sector is at the blast furnace/crude steel making stage. Typical energy conservation/productivity improvements result from:

- improved control over-burden preparation
- improved process control
- injection of pulverised fuel to substitute coke
- better energy recovery from top gas and from using the high top pressures employed in modern furnaces to drive the turbine
- longer campaign life through improved refractory and cooling systems
- alternative form of heat energy etc.

**Table 6.1.** Comparison of energy efficiency of Indian plants vis-a-vis other countries

	Energy consumption in Gcal per tonne of crude steel	Coke rate
Italy	4.2	463
Japan	4.5	484
U.K.	5.6	557
Brazil	5.7	480
India	9.8-13.7	735-1188

**Source:** GOI (1989a)..

A study carried out by the Bureau of Industrial Costs and Prices on particular steel plants points out the possibility of reducing energy consumption in these plants from the present level of 7.2 to 8 Gcal/metric tonne of crude steel to a level of 5.5 Gcal/metric tonne. Extrapolating this for other steel plants it is estimated that the investments that would be required for achieving this level of efficiency improvements would be in the range of \$10994.8 million for integrated steel plants. Since capacity additions in this sector remains the same for 5 and 6 per cent rate of growth of GDP scenarios, investment requirements for energy conservation remains the same.

(b) Cement: In the case of cement industry it has been assumed that the remaining wet process capacity in cement production under BAU would be completely replaced by the dry process technology. An additional 10 per cent reduction on

the specific consumption norms for the dry process by close circuiting of the cement mill by installation of high efficiency separator, X-Ray analyser for speedy process control and replacement of low efficiency fans by high efficiency ones have been considered. The investment requirements for doing the above have been estimated at \$767 million.

(c) Chemicals and petro-chemicals: A case study of the National Organic Chemical Industry Ltd. (NOCIL) which succeeded in achieving a specific fuel consumption level of 0.947 tonne of naphtha equivalent fuel per tonne of output against the prevailing level of 1.257 tonne per tonne of output through specific energy conservation measures has been used for studying the implications of energy conservation in this sector. It has been estimated that a minimum reduction of 20 per cent is absolutely essential for firms to be financially viable. To achieve an energy savings of 20 per cent in the organic chemicals sector an investment of \$483 million has been estimated. The major non-organic chemicals wherein energy conservation could be effective are soda ash and caustic soda. While there has been no major technological breakthrough in the production of soda ash, industry experts are of the opinion that the requirement from the membrane cell technology for producing caustic soda would be as low as 40 per cent of the present level. To achieve an energy savings of 30% in this sector and investment requirement of \$1318 million has been estimated.

6.2.1.2 Transport sector: The following measures that are likely to result in reduced energy consumption levels in transportation have been taken into account:

(1) A shift from road transportation to rail transportation for both passenger and freight traffic. The National Transport Policy Committee of the Government of India had recommended a rail-road mix of 40:60 in passenger transportation and 72:28 for freight transportation. It has been assumed that this mix would be achieved by the year 2009-10 from the present levels of 21:79 for passenger transportation and 51:49 for freight transportation.

(2) The road user cost study again by the Government of India has estimated 10 per cent fuel efficiency improvements due to various measures adopted for improving road conditions. The range of road improvement measures include low grade section to be updated and widened, single lane road to be widened and strengthened, strengthening two lane pavement etc.

This has been adopted here. Road improvements also bring other benefits like improvement in tyre life, engine life, etc., which is not accounted for in the present study.

(3) Introduction of more efficient buses (termed as urban bus) for intra-city passenger transportation could lead to an efficiency improvement of 10 per cent. Urban bus has a design capacity of 60 and crush loading of 90. It has low floor height with a new and more efficient engine. It is fuel efficient and at lower speeds emits less pollutants. Urban bus is faster than the standard bus under urban conditions due to better acceleration. Its weight is less because of the use of lighter material. The investments that would be required for effecting the above savings are to the tune of \$69799 million.

(4) At present, the only urban rail transport system in India are in Bombay and Calcutta. Urban rail transport systems lead to a reduction in energy consumption and emission reduction. A detailed feasibility report prepared by Rail India Technical and Economic Services (RITES) for the city of Delhi from the basis for analysis. It is estimated that the metro system on an average would cost US\$ 1.39 billion and provide a capacity of 20 BPKM annually. In the present study, urban rail transport (metro) in Madras and Delhi and seven cities with population between 2 and 8 million has been recommended. Feasibility of a metro in the North-East region is not considered because of low density corridors. The capital (including the interest) required is spread out at the rate of 40%, 30%, 20% and 10% for the periods 1994/95, 1999/2000, 2004/05 and 2009/10 respectively.

6.2.1.3 Domestic sector: Efficiency improvements in this sector can take place in the following activities : cooking, lighting, water heating and other electrical appliances.

(a) Cooking: It has been assumed that there exists potential for a 5% improvement in the present average efficiency of LPG stoves the turn of the century and by 10 per cent by the year 2009-10. In case of kerosene stoves and cookstoves using soft coke an efficiency improvement of 10 per cent has been considered for each of the years under study.

(b) Lighting: For lighting purposes, the option of replacing incandescent bulbs with fluorescent tubes has been considered. We analyse the case where all the additional

incandescent bulb connections in the households as per the BAU-scenario will get replaced by half as many fluorescent connections. This is because the lumen output of one 40 watt 4 feet long fluorescent tube is approximately the same as that of 2 incandescent bulbs of 100 watts each. If, however, a 40 watt fluorescent tube was used to replace two 60 watts incandescent bulbs, the lumen output would actually increase [TERI (1990)].

(c) Other electrical appliances: The Tata Energy Research Institute had recently carried out a survey of energy efficiency of domestic appliances in use today [TERI (1991)]. On the basis of the results of this study, in case of air-conditioners, a 20 per cent efficiency improvement over the present levels has been assumed through proper maintenance of air-conditioning systems alone. In the case of refrigerators, an efficiency improvement of 30 per cent resulting from minor maintenance and regular defrosting is assumed by the year 1999-2000. From 1999-2000 to 2009-10 it has been assumed that 25 per cent of the old stock will get replaced by more energy efficient refrigerators. For the balance 75 per cent regular maintenance will result in a 30 per cent energy conservation. In case of ceiling fans, a small efficiency improvement of 5 per cent in energy consumption is assumed to be achievable by minor maintenance measures such as regular greasing etc. The investments that would be required for implementing the above mentioned measures are estimated in the range of \$3699 million. The aggregate energy requirements for all the measures listed above [(a) (b) & (c)] amount to about \$3700 million.

2.1.4 Agriculture sector: One of the major end-uses for which energy is consumed in the agricultural sector is irrigation. Table 6.2 summarizes the expected savings from the various retrofit measures that have been considered and the distribution of pumpsets on which each of these measures would be applied. The investments that would be required for implementing these retrofit measures are of the order of \$578.7 million.

Further, an option of more efficient irrigation practice has also been considered. Thus, the option of using drip irrigation for crops such as sugarcane, cotton and oilseeds and sprinkler irrigation for maize and gram has been considered with application efficiency of 95 per cent and 85 per cent respectively against present application efficiencies of less than 50 per cent. Investments that would be required for installing these irrigation systems are approximately \$11309 million.

**Table 6.2.** Expected savings from different retrofit procedures<sup>a</sup>

Retrofit measures	per cent of pumpsets	Expected savings
Involving subsystem components		
1. Replacement of foot valve and suction pipeline (R <sub>1</sub> )	30	8-12
2. Replacement of foot valve, suction, and delivery pipeline (R <sub>2</sub> )	40	10-20
Involving subsystems		
3. R <sub>2</sub> + replacement of pump (R <sub>3</sub> )	10	20-40
Involving entire system		
4. R <sub>3</sub> + change of motor (i.e. complete replacement) (R <sub>4</sub> )	20	30-50

<sup>a</sup> Abridged from Patel 1988.

#### 6.2.2 Measures on the supply side

The major improvements considered in the performance of the energy supply industries are:

- (i) a reduction in T & D losses, from 23% in the BAU strategy, to 18% in the conservation strategy. Of this reduction of 5%, about two-thirds may be considered to be in non-technical losses --- which implies that certain institutional constraints are partly removed;
- (ii) non-coking coal washeries, for reducing ash content of steam grade coal used for thermal power generation, are established.

No significant improvements in the production efficiencies of coal and oil subsectors are assumed.

T & D losses are assumed to reduce from the present level of 23%, to 22.5% in 1999/2000, and further on to 20.5% by 2004/05 and 18% by 2009/10. Further, it is assumed that washing of non-coking coals reduces their ash content by about 7%. With this, the performance of the TPS will enhance, with an improvement in the plant heat rate from 2336 kCal/kWh to 2304 kCal/kWh, a reduction in auxiliary consumption levels from 10% of gross generation to 9.58%, a reduction in coal utilization from 0.65 kg/kWh of gross generation to 0.44 kg/kWh (even if washery rejects are 20% of the coal feed, the input coal requirements are 0.55 kg/kWh), and a reduction in the oil use from 15ml/kWh to 10 ml/kWh.

These performance indicators are derived from relationships presented in Appendix 6.1. The results are given in section 6.4.

## **strategy II: Alternative energy options for meeting energy demands**

In addition to efficiency improvements and demand management, there exists potential to develop alternative energy forms and substitutes towards the use of more environmentally benign energy sources. This strategy looks at the impact of doing so.

### **Demand side**

Alternative energy options that have been on the demand side include the use of solar cookers, biogas plants and compressed natural gas as a transportation fuel.

On the basis of a recent analysis carried out by the Tata Energy Research Institute, it was found that the solar cooker is an economically attractive option only in small and medium sized towns and cities. Taking the present proportion of urban population for these cities (40 per cent) and assuming a penetration ratio of 20 per cent, savings in LPG consumption have been worked out. The same analysis indicated that solar cookers would be able to replace 20 per cent of LPG for cooking energy demands.

In considering the option of compressed natural gas as a transportation fuel, the transportation requirement of only those cities that are situated close to existing gas pipeline network were taken into account. The number of vehicles that could be converted to using compressed natural gas were obtained from Srinivas (1991). Test results have shown the efficiency of buses and trucks based on compressed natural gas to be in the range of 7.42 km/m<sup>3</sup> and of cars at 10.27 km/m<sup>3</sup>. Investments that would be required for the utilization of CNG to this extent are in the range of 1.1 million of rupees.

The costs that have been taken into account include the costs of refueling station, distribution pipelines and operating costs. Costs of trunk pipelines have not been considered. This option is assumed to remain the same under both the scenarios.

In the case of biogas plants, it was assumed that the cumulative number of biogas plants will go up to 5.53 million of 2 m<sup>3</sup> capacity would be installed by the year 2010 under this scenario. Correspondingly, the number of cook stoves using biogas would also increase. This would have a dual



impact on firewood consumption - first, through substitution of firewood by biogas and the second, through the higher efficiency of biogas stoves. Total investment that are required for this option are approximately \$1163 million.

#### 6.3.2 Supply side

The major changes on the supply side are the augmentation of power generating capacity through RETs, mainly windfarms and small hydro capacity. In view of the constraints mentioned in Chapter 5, a realisable target of 3000 MW of windfarms and 1500 MW of small hydel capacity can be added till 2010. Based on design considerations keeping strategy evaluation in view (section 6.1), the regional distribution of the generating capacities considered are given in Table 6.3.

**Table 6.3.** Power Generating Capacity additions from RETs in the 5% GDP growth case (MW) - Strategy II

	April 1990 to March 1995	April 1995 to March 2000	April 2000 to March 2005	April 2005 to March 2010
-----				
Northern Region				
- Windfarms	0	0	0	0
- SHP	31	93	155	217
Western Region				
- Windfarms	33.75	56.25	90	112.5
- SHP	15	45	75	105
Southern Region				
- Windfarms	33.75	56.25	90	112.5
- SHP	35	105	175	245
Eastern Region				
- Windfarms	7.5	125	200	250
- SHP	10	30	50	70
North-eastern Region				
- Windfarms	0	0	0	0
- SHP	9	27	45	63
All India				
- Windfarms	75	237.5	380	475
- SHP	100	300	500	700
-----				

These capacity additions are assumed for both the low and high GDP growth cases. In order to assess the acceptable levels of penetration (% of the peak generating capacity) of wind electric generators in the regional power systems in

India, the working of one utility was studied for cost and reliability. The power system operated by Tamil Nadu Electricity Board (TNEB) was simulated with different levels of penetration of windfarms. The major findings of this exercise are:

- (i) energy rejection increases significantly beyond the 35% penetration level;
- (ii) system reliability is not adversely affected by windfarm penetrations of up to 35%;
- (iii) fuel and running cost savings are not significant beyond a penetration of 35%; and
- (iv) the contribution of wind generation in meeting peak load demand is small but could increase to 10% of peak demand if a large number of sites are considered.

The operation and nature of the generation mix of other utilities in India is similar to TNEB. The findings of this exercise, therefore, are assumed to hold for other utilities as well. Although the technically realizable potential of windfarms in India can be computed on the basis of a 35% level of penetration, the actual installations will remain much lower despite special efforts.

On the basis of the sites identified so far, the potential for microhydel units is estimated at 5000 MW. The ultimate potential in both grid connected and decentralised modes however, is very large. At present, the capacity of small units is only 0.55 MW. Although there are eight manufacturers of small hydro turbines, their production capacity is small. Several canal drop schemes and other small/mini hydro plants have been cleared, but their execution is likely to be delayed owing to lack of funds, difficult logistics and lack of experience in this field. The critical constraint will be the production capacity of turbines in the range of 50 kW to 500 kW.

#### **Demand/supply situation resulting from the above two strategies**

##### **Demand impacts**

As can be seen from table 6.4 below significant reductions can be affected in energy demands through the measures suggested above. However, no clear pattern of savings emerges in sum as what is presented below is the net savings across sectors. Electricity and coal demands do not undergo any change under Strategy II whereas firewood consumption remains

the same in strategy I. Table 6.4(a) presents the percentage change in demand for these fuels whereas, Table 6.4(b) gives the percentage changes in oil and gas demand due to implementing both the strategies independently.

**Table 6.4(a).** Energy savings under the 5% growth scenario

	Electricity		Coal		Firewood	
	BAU	Strategy I	BAU	Strategy I	BAU	Strategy II
	(GWh)	% change	(MT)	% change	(MT)	% change
<b>1994-95</b>						
North	91431	18.61	59.85	4.25	24.60	5.10
South	72228	12.54	63.38	11.40	37.69	4.63
West	90863	12.00	103.19	9.73	50.83	4.52
East	46056	14.12	85.42	21.21	25.84	3.66
N East	3597	9.93	2.94	13.39	8.03	2.97
All India	304175	14.41	314.78	12.17	146.99	4.41
<b>1999-00</b>						
North	112487	15.97	78.13	13.87	26.77	6.83
South	95233	11.72	84.09	19.09	39.43	6.30
West	116019	10.13	125.03	16.06	55.23	6.03
East	56358	12.21	100.29	24.07	28.72	4.79
N East	4563	2.17	2.86	4.96	8.87	3.92
All India	384661	12.44	390.40	18.25	159.02	5.89
<b>2004-05</b>						
North	143054	14.57	103.99	23.86	28.95	8.63
South	126796	11.21	108.31	14.65	41.13	8.06
West	153349	9.35	154.01	11.84	59.34	7.63
East	71760	9.21	121.06	20.59	31.95	5.86
N East	6153	-2.07	4.64	-1.85	9.86	4.80
All India	501113	11.15	492.01	17.02	171.24	7.41
<b>2009-10</b>						
North	186100	11.66	143.90	25.49	31.29	10.45
South	174379	8.34	148.55	11.99	42.83	9.90
West	209247	5.31	195.68	9.29	63.70	9.24
East	94401	5.27	154.53	21.56	35.57	6.87
N East	8466	-10.86	4.85	-6.51	10.97	5.64
All India	672593	7.64	647.51	16.11	184.36	8.93

Table 6.4(b). Energy savings under the 5% growth scenario

	Oil			Natural Gas		
	BAU	Strategy I	Strategy II	BAU	Strategy I	Strategy II
	(MT)	% change	% change	(MCM)	% change	% change
1994-95						
North	22.07	30.77	0.01	8108.66	12.25	neg.
South	17.19	22.64	0.02	2796.16	21.64	neg.
West	23.83	17.72	0.01	9375.44	4.35	neg.
East	12.82	35.29	0.01	707.90	0.00	neg.
N East	2.01	31.15	0.01	2339.16	16.89	neg.
All India	80.14	25.03	0.01	23327.31	10.58	neg.
1999-00						
North	29.73	21.98	0.01	11515.22	17.65	neg.
South	22.31	20.56	0.01	4704.20	13.66	neg.
West	30.41	17.42	0.01	15082.63	4.55	neg.
East	17.03	25.11	0.01	906.10	0.00	neg.
N East	2.62	26.37	0.01	4539.76	8.79	neg.
All India	104.82	20.40	0.01	36747.92	11.00	neg.
2004-05						
North	38.66	26.26	3.04	13338.67	15.31	-10.98
South	28.29	23.70	0.60	6268.68	10.57	-3.62
West	38.62	20.70	1.63	19420.72	3.76	-4.15
East	22.06	28.79	0.76	1139.39	0.00	-19.92
N East	3.35	32.10	2.50	6636.51	6.05	-1.70
All India	134.33	24.03	1.66	46803.97	9.40	-6.06
2009-10						
North	50.85	29.23	4.62	16052.35	13.27	-18.24
South	36.48	25.17	0.93	8805.19	-4.93	-5.16
West	49.82	21.40	2.51	26324.96	-11.48	-6.12
East	28.87	31.28	1.16	1444.97	0.00	-31.42
N East	4.32	36.64	3.84	9969.11	4.23	-2.28
All India	174.46	25.98	2.55	62596.58	0.16	-9.06

Electricity savings are seen to be much larger in the short-term as compared to the long-term. This is because in the long-term we have assumed a larger shift to electrified routes for transportation. The largest savings potential is in the northern region followed by the eastern region up to the turn of the century and the southern region in the next decade. Coal savings are seen to be fluctuating -- increasing from 12 per cent in 1994/95 to 18 per cent in 1999/2000 but reducing again to 16 per cent in the year 2009/10. Firewood savings increase from 4.4 per cent in 1994/95 to close to 9 per cent in 2009/10.

In the case of oil consumption very significant savings in the range of 20 to 25 per cent are noticed under the

conservation strategy and small savings under the alternative energy strategy where essentially LPG is getting replaced by solar cookers and some savings are effected in the consumption of motor spirit and high speed diesel as a result of switching over to compressed natural gas. Correspondingly natural gas consumption in Strategy II actually increases.

A sectoral picture of energy savings is given in table 6.5 below. The largest savings potential is seen to be in agricultural sector for electricity followed by the domestic sector. Coal savings in the range of 15-20% are possible in both the major consuming sectors of power and industry. The maximum reduction in oil consumption is noticed in the transportation sector which has largely been due to the modal shifts that have been assumed.

**Table 6.5.** Energy savings under the 5% growth scenario for 2009-10

		% Change			
	BAU	Strategy I	Strategy II	Strategy I	Strategy II
-----					
ELECTRICITY (TWh)					
Industry	359.4	342.5	359.4	4.68	0.00
Transport	13.0	32.7	13.0	-151.55	0.00
Domestic	94.9	86.1	94.9	9.30	0.00
Agriculture	138.0	97.7	138.0	29.20	0.00
TOTAL	672.6	621.2	672.6	7.64	0.00
COAL (MT)					
Industry	184.9	148.8	184.9	19.49	0.00
Power	389.3	324.4	389.3	16.66	0.00
Transport	3.8	11.4	3.8	-198.21	0.00
Domestic	3.3	3.0	3.3	9.20	0.00
TOTAL	645.9	541.8	645.9	16.11	0.00
OIL (MT)					
Industry	33.8	30.7	33.8	8.99	0.00
Power	8.8	6.8	8.8	22.76	0.00
Transport	89.4	54.8	85.2	38.64	4.73
Domestic	21.7	19.5	21.7	10.00	0.00
Agriculture	9.6	8.1	9.6	15.00	0.00
TOTAL	174.5	129.1	170.0	25.98	2.55
Natural Gas (BCM)					
CNG			5.7		
Industry	23.9	22.0	23.9	8.02	0.00
Power	38.7	40.5	38.7	-4.70	0.00
Total	62.6	62.5	68.3	0.16	-9.06
FIREWOOD (MT)					
Rural	153.3	153.3	136.9	0.00	10.74
TOTAL	184.4	184.4	167.9	0.00	8.93

Energy savings for the 6% growth scenario are given in Table 6.6. The percentage savings are quite different from those in the 5% growth scenario as the mix of industries is significantly different.

**Table 6.6.** Energy savings under the 6% growth scenario for 2009-10

	BAU	Strategy I	Strategy II	% Change	
				Strategy I	Strategy II
Electricity (TWh)	727.6	668.8	727.6	8.07	0.00
Coal (MT)	768.9	671.6	768.9	12.66	0.00
Oil (MT)	187.4	141.6	182.8	24.43	2.44
Natural gas (BCM)	70.2	65.9	75.9	6.10	-8.08
Firewood (MT)	175.6	175.6	166.8	0.00	5.03

## 2 Power sector

With the improvements in the power sector in the conservation strategy, and given the power demand forecasts, the required increases in generation capacity are considerably lower than in the BAU strategy of development. However, additions of windfarms and small hydropower capacity are assumed to be as in the BAU strategy. In the 5% per annum GDP growth case, the capacity additions in successive five-year intervals from 1990/91 to 2009/10 are given in Table 6.7. In the 6% per annum GDP growth case, the additions to despatchable generating capacity during the four successive five year intervals from April 1990 to March 2010 are 25942 MW, 27440 MW, 32930 MW and 47390 MW respectively. It may be noted that it is assumed that coal will be washed for power generation in Northern, Western and Southern Regions only -- where in general, it is transported over relatively long distances by rail.

In the 5% GDP growth case, about 40,100 MW of generation capacity is added during the 1990s, compared to about 54,900 MW in the BAU strategy. From 2000/01 to 2009/10, the capacity additions are 75,500 MW, compared to over 86,200 MW in the BAU strategy. However, an important difference is that even with lower capacity additions in this strategy, the projected power shortages (both in terms of peak and energy) are rather small (Table 6.8).

Additions of conventional power generating capacity in the alternative energy strategy will be the same as in the BAU strategy. However, owing to the additions of RET capacity, power shortages will reduce considerably from BAU levels (Table 6.8), and grid expansion requirements at 33kV and lower voltage levels will be slightly higher than in the BAU strategy.

**Table 6.7. Power Generating Capacity Additions in 5% GDP Growth Case (MW) - Strategy I**

	April 1990 to March 1995	April 1995 to March 2000	April 2000 to March 2005	April 2005 March 2010
<b>Northern Region</b>				
Hydro	1768	4947	4429	2420
TPS	840	1370	-	500
TPS/Washery	210	630	1630	4890
GT/CCP	1528	715	300	475
Nuclear	470	470	1000	1589
Total	4816	8132	7359	9874
<b>Western Region</b>				
Hydro	1303	250	1223	1900
TPS	1550	2330	3140	1840
TPS/Washery	-	420	2360	5900
GT/CCP	2200	1745	900	3530
Nuclear	470	-	500	795
Total	5523	4745	8123	13965
<b>Southern Region</b>				
Hydro	1145	1000	598	1431
TPS	1260	2100	4610	3300
TPS/Washery	-	-	210	3860
GT/CCP	560	478	290	1106
Nuclear	-	470	940	1494
Total	2965	4048	6648	11191
<b>Eastern Region</b>				
Hydro	1371	82	1100	2604
TPS	2940	3150	4050	5210
Total	4311	3232	5150	7814
<b>North-eastern Region</b>				
Hydro	371	222	651	2145
GT/CCP	712	1062	1000	1589
Total	1083	1284	1651	3734
<b>All India</b>				
Hydro	5957	6500	8000	10500
TPS	6590	8950	11800	10850
TPS/Washery	210	1050	4200	14650
GT/CCP	5000	4000	2490	6700
Nuclear	940	940	2440	3878
Total	18697	21440	28930	46578

**Table 6.8. Peak Demand and Energy Shortages**

	1994/95	1999/00	2004/05	2009/10
<b>Strategy I</b>				
<b>5% GDP Growth Case</b>				
% Peak shortage	3	4	5	4
% Energy shortage	~	~	2	2
<b>6% GDP Growth Case</b>				
% Peak shortage	5	3	3	2
% Energy shortage	~	~	~	~
<b>Strategy II</b>				
<b>5% GDP Growth Case</b>				
% Peak shortage	15	9	10	10
% Energy shortage	6	~	~	~
<b>6% GDP Growth Case</b>				
% Peak shortage	22	16	15	10
% Energy shortage	14	7	5	~

~ : < 0.5%

In the conservation strategy, investment levels in the power sector are considerably lower than in the BAU strategy, even if washery costs are added (Table 6.9). Capital costs of a washery are estimated at \$3.57 million/mtpa and a capacity utilization factor of 90% is assumed. For T & D loss reduction, it is assumed that only one-third of the loss reduction achieved in any year will be technical losses -- the rest will be due to reduction of pilferage, improved billing procedures, better metering etc., which entail little investment.

In the alternative energy strategy, investment levels are different from the BAU strategy only to the extent more windfarms and small hydro capacity are installed.

The fuel inputs required for power generation in both the strategies have been incorporated in the energy demand projections.



**Table 6.9. Investment requirements in the Power Sector**  
(\$ million)

	1990/91 to 1994/95	1995/96 to 1999/00	2000/01 to 2004/05	2005/06 to 2009/10
Strategy I				
5% GDP growth case				
Washeries	2.51	12.53	50.11	174.79
Despatchable generation tech	11654	14512	20887	34746
Renewable generation tech	308	441	574	983
T & D Systems expansion	7769	9675	13925	23164
T & D Loss reduction	0	273	1333	2367
Total	19733	24914	36769	61434
6% GDP growth case				
Washeries	5.01	17.54	75.17	226.7
Despatchable generation tech	16056	18606	23626	35103
Renewable generation tech	308	441	574	983
T & D systems expansion	10704	12404	15751	23402
T & D loss reduction	0	313	1468	2454
Total	27074	31781	41494	62169
Strategy II				
5% GDP growth case				
Total investment	26428	34663	43861	70215
of which :				
- on RETs	308	758	1250	1700
6% GDP growth case				
Total investment	27074	37262	49359	82830
of which :				
- on RETs	308	758	1250	1700

#### 6.4.3 Coal and lignite situation

The indigenous production of coking and non-coking coals as well as lignite remain the same as in the BAU strategy, and so do investment requirements (see chapter III). However, the demand, both for power generation and other uses is considerably reduced in the conservation strategy. Table 6.10 gives the regional coal availability situation vis-a-vis production in both the low and high GDP growth cases. Again, the Eastern Region will be supplying both coking and non-coking coals to other regions of the country. If production levels are maintained as in the BAU strategy, there will be an overall surplus of non-coking coals in the low GDP growth case. In the high GDP growth case, the overall coal deficits are significantly lower than in the BAU strategy. Nevertheless, India would still need to undertake a massive effort to develop port facilities.

In the alternative energy strategy, coal and lignite demand and supply situations remain unchanged from BAU strategy levels.

**Table 6.10. Regional coal imports - Strategy I**  
(MT per year)

	1994/95	1999/00	2004/05	2009/10
<b>Non-coking Coal (5% GDP Growth Case)</b>				
NR	57.45	67.42	79.21	105.01
WR	6.04	5.80	20.37	47.01
SR	5.68	7.43	20.22	44.35
ER	-88.89	-147.50	-206.97	-279.08
NER	-0.50	-1.62	-0.83	3.55
INDIA	-20.22	-68.47	-88.00	-79.16
<b>Non-coking Coal (6% GDP Growth Case)</b>				
NR	64.59	79.79	98.08	134.51
WR	12.32	23.18	48.96	93.90
SR	14.03	27.25	51.17	88.49
ER	-87.35	-144.01	-201.70	-275.35
NER	-0.50	-1.59	-0.71	3.83
INDIA	3.09	-15.38	-4.20	45.38

#### Oil Situation

In the conservation strategy, both the indigenous crude oil production and refining capacity and complexity remain the same as in the BAU strategy; so do investment levels. However, as the demands for various products are relatively lower in the conservation strategy, India's self-sufficiency in refining capability increases. In the low GDP growth case, refining capacity (as a percentage of demand), increases to nearly 100% by 2009/10. However, as the capacity utilization of refineries is assumed to be 90% (as in the BAU strategy) and refinery losses at 6%, total refinery production will be considerably lower than demand. In the high GDP growth case, refining capacity accounts for about 91% of the demand in 2009/10. Table 6.11 summarises the results. It is evident that India will continue to import middle distillates as well as heavy ends. However, there will be small surpluses of light distillates for exports.

The demands for refined products in the alternative energy strategy are marginally, below that in the BAU strategy. Therefore, the crude import levels will be the same as in the BAU strategy but total product import requirements somewhat less -- for products that are exported, the exportable quantities increase somewhat. However, the deficits of middle distillates (particularly HSD) remain high.

**Table 6.11. Oil supply situation**

(MT per annum)

	Strategy I				Strategy II			
	1994/95	1999/00	2004/05	2009/10	1994/95	1999/00	2004/05	2009/10
<b>5% and 6% GDP Growth Case</b>								
Refining Capacity	61.8	81.6	105.3	138.4	61.8	81.6	105.3	138.4
Crude Throughput	55.6	73.4	94.7	124.5	55.6	73.4	94.7	124.5
<b>Refinery Output</b>								
-Total	52.3	69.0	89.0	117.1	52.3	69.0	89.0	117.1
-Light Distillates	10.9	14.7	19.3	25.8	10.8	14.7	19.3	25.8
-Middle Distillates	29.1	39.1	51.1	68.0	29.1	39.1	51.1	68.0
-Heavy Ends	12.3	15.2	18.6	23.4	12.3	15.2	18.6	23.4
<b>5% GDP Growth Case</b>								
<b>Net Imports</b>								
-Crude	20.1	30.2	41.4	54.0	20.1	30.2	41.4	54.0
-Light Distillates	0.4	-1.3	-3.2	-5.5	1.4	0.7	0.2	-0.8
-Middle Distillates	7.7	16.4	16.3	15.0	25.9	33.8	39.9	47.7
-Heavy Ends	3.9	4.7	6.8	11.9	5.2	7.3	10.9	16.8
<b>6% GDP Growth Case</b>								
<b>Net Imports</b>								
-Crude	18.0	25.5	32.7	38.5	18.0	25.5	32.7	38.5
-Light Distillates	0.7	-0.04	-1.9	-5.5	2.0	1.9	1.3	-1.1
-Middle Distillates	9.5	20.4	32.1	25.4	27.8	38.1	56.2	58.8
-Heavy Ends	4.9	6.6	9.3	14.7	5.8	8.3	12.6	19.6

**6.4.5 Gas situation**

In the conservation strategy, the demand for natural gas is lower than in the BAU strategy -- and so is gas production from free gas fields. The production of associated gas remains as in the BAU strategy. All natural gas requirements will be met through indigenous sources.

Table 6.12 gives the capital investment requirement for pipelines on land and off-shore. Owing to the fact that the gas demand in 2009/10 is relatively lower in the conservation strategy, the total capital requirements over the twenty year time period are less. However, the investment in one of the five-year intervals for which data are shown may be more -- depending on the additional gas demand during that particular five year period.

**Table 6.12. Investment for Natural Gas Pipelines - Strategy I**

	1990/91 to 1994/95	1995/96 to 1999/00	2000/01 to 2004/05	2005/06 to 2009/10
5% GDP Growth Case				
Pipelines (\$ million)				
-onland	1725	2108	1727	3576
-offshore	1294	740	1002	2530
-Total	3019	2848	2729	6106
6% GDP Growth Case				
Pipelines (\$ million)				
-onland	2285	2205	1904	3354
-offshore	1468	974	1366	3354
-Total	3754	3179	3270	6708

Owing to a substantial increase in gas demand in the alternative energy strategy, indigenous gas production is considerably larger than in the BAU strategy. Even in this strategy, it is possible to meet additional gas requirements by increasing the production from free gas fields. The investment levels required for gas pipelines are also concomitantly higher than in the BAU strategy, as shown in Table 6.13.

**Table 6.13. Investment for natural gas pipelines - Strategy II**

	1990/91 to 1994/95	1995/96 to 1999/00	2000/01 to 2004/05	2005/06 to 2009/10
5% GDP Growth Case				
Pipelines (\$ million)				
-onland	2164	2389	2295	3316
-offshore	1294	740	1002	2530
-Total	3458	3129	3297	5846
6% GDP Growth Case				
Pipelines (\$ million)				
-onland	2380	2619	2663	3859
-offshore	1468	974	1366	3354
-Total	3848	3593	4028	7212

#### Combination of Strategies I and II

The impact of efficiency improvements, demand management, fuel substitution and the rapid penetration of RETs considered in the above strategies are included here.

**Table 6.14.** Energy savings from implementing both the above strategies (5% GDP growth)

	Unit	BAU Strategies I & II		% change
Electricity	TWH	673	621	7.64
Coal	MT	646	542	16.11
Oil	MT	175	125	28.41
Natural gas	Bcm	63	68	-8.90
Firewood	MT	184	168	8.93

Total energy savings in the demand sector, are for the 5% GDP growth case as given in Table 6.14. In terms of million tonnes of oil equivalent of saving, this works out to approximately 50 MTOE/annum. Investment requirements for affecting the above savings work out to roughly Rs. 900 billion. Energy savings under the 6% growth scenario are given in Table 6.15.

**Table 6.15.** Energy savings from implementing both the above strategies (6% GDP growth)

	BAU	Strategies I & II	% change
Electricity	728	669	8.07
Coal	769	672	12.66
Oil	187	137	26.88
Natural gas	70	72	-1.98
Firewood	176	167	5.03

**Power Availability:** With additions to despatchable generation capacities as in Strategy I and RET capacities as in strategy II, the peak power and energy deficits disappear in most cases (Table 6.16) -- an indication that the power system reliability will be good.

Investments are correspondingly higher than in the conservation strategy and are \$19733 million, \$25231 million, \$37445 million and \$62151 million (including investment in washeries) in the 5% GDP growth case in successive five year intervals from 1990/91 to 2009/10. In the 6% GDP growth case, the corresponding investment levels are \$27074 million, \$32098 million, \$42169 million and \$62886 million respectively.

**Table 6.16.** Combination strategy -- Peak power and energy deficits

	1994/95	1999/00	2004/05	2009/10
<b>5% GDP Growth Case</b>				
% peak shortages	3	4	4	3
% energy shortages	~	~	~	~
<b>6% GDP Growth Case</b>				
% peak shortages	5	3	2	1
% energy shortages	~	~	~	~

~ : < 0.5%

Coal: Coal requirements remain as in the conservation strategy. So do coal production levels, and consequently regional and national shortages and surpluses.

Oil: Oil demands reduce from the conservation strategy levels, and so do the net import requirements of various products (Table 6.17). Major shortages of middle-distillates (particularly HSD) however, continue.

As indigenous crude production levels and refining capacity (along with its utilization and complexity) remain as in other strategies, so do crude oil imports.

**Table 6.17.** Combination strategy -- net petroleum imports (MT per annum)

	1994/95	1999/00	2004/05	2009/10
<b>5% GDP Growth Case</b>				
Crude	20.1	30.2	41.4	54.0
Light Distillates	0.3	-1.4	-3.6	-6.2
Middle Distillates	7.7	16.4	16.3	15.0
Heavy Ends	3.9	4.7	6.8	11.9
<b>6% GDP Growth Case</b>				
Crude	19.0	25.5	32.7	38.5
Light Distillates	0.6	-0.2	-2.3	-6.1
Middle Distillates	9.5	20.4	30.1	21.4
Heavy Ends	4.9	6.6	9.3	14.7

Gas: Compared to the conservation strategy, there is a significant increase in natural gas demand. This additional gas demand will be met by increasing the output from free gas fields. In fact, the free gas production requirements remain

substantially below the free gas production potential in the low GDP growth case, although the latter will only be marginally higher than the former in the high GDP growth case. Investment requirements for gas pipelines are given in Table 6.18.

**Table 6.18.** Combination Strategy -- Investments Required Natural Gas Pipelines

	1990/91 to 1994/95	1995/96 to 1999/00	2000/01 to 2004/05	2005/06 to 2009/10
5% GDP Growth Case				
Pipelines (\$ million)				
-onland	1725	2108	2232	4081
-offshore	1294	740	1002	2530
-Total	3019	2848	3234	6611
6% GDP Growth Case				
Pipelines (\$ million)				
-onland	2285	2205	2409	3859
-offshore	1468	974	1366	3354
-Total	3754	3179	3775	7213

## Appendix 6.1

The use of washed coal has several implications on the cost and performance of TPS units. Empirical relationships have been developed, on the assumption that a TPS unit normally uses coal with a gross calorific value (GCV) of 4500 kCal/kg, and ash content (AC) of 36.6%. In fact, Bharat Heavy Electricals Ltd. (BHEL) manufactures boilers designed to burn such coal. As coal of GCV of 4000 kCal/kg has AC of 40%, the following relationship emerges :

$$\text{GCV} = 10000 - 150 \cdot \text{AC} \text{ ----- (1)}$$

According to Natarajan and Suri (1982), a 15% increase in ash content results in an increase in the boiler cost by 9% and of the coal handling plant (CHP) plus ash handling plant or AHP (including electrostatic precipitators or ESP) by 10%. These observations form the basis for the following relationships:

$$\text{KB}_{\text{wash}} = \text{KB} \cdot (4500/\text{GCV})^{(0.16)} \text{ ----- (2)}$$

$$\text{KC}_{\text{wash}} = \text{KC} \cdot (4500/\text{GCV})^{(0.177)} \text{ ----- (3)}$$

where KB = boiler cost in a TPS unit using normal unwashed non-coking coal (Rs./kW);

KB<sub>wash</sub> = boiler cost in a TPS unit using washed coal (Rs./kW);

KC = Capital cost of CHP plus AHP (excluding ESP) in a TPS unit using normal unwashed non-coking coal (Rs./kW); and KC<sub>wash</sub> = Capital cost of CHP plus AHP (excluding ESP) in a TPS unit using washed coal (Rs./kW).

For estimating reductions in capital costs of TPS units, it is further assumed that the boiler comprises 33% of total capital costs and the CHP plus AHP (excluding ESP) about 17% of the total costs of a TPS unit using unwashed non-coking coal.

Tests of using washed coal in TPS units were made at the Satpura TPS (Western Region). These tests showed that for a GCV increase of 1500 kCal/kg (12% coal reduction), the boiler efficiency increases by about 3%. As Bharat Heavy Electricals Ltd. (BHEL) manufactures boilers having an efficiency of 86%, the following empirical relationship may be derived:



$$EB_{wash} = 0.86 * (GCV/4500)^{(0.12)} \text{-----} (4)$$

Where  $EB_{wash}$  = efficiency of boiler using washed coal (fraction).

Further, BHEL also guarantees a heat rate of 2009 kCal/kWh for its units, which implies that:

$$HR_{wash} = 2009 / EB_{wash} \text{-----} (5)$$

Where  $HR_{wash}$  = heat rate of a TPS unit running on washed coal.

Other assumptions that are made are:

- (i) TPS availability increases by 1% as AC decreases by 1% -- this underestimates the claims made in India;#
- (ii) Auxiliary consumption reduces by 0.06% for every 1% reduction in AC; and
- (iii) Oil support reduces by 0.715 ml/kWh for every 1% decrease in AC.

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 # It is reported that at the Chandrapur TPS in Maharashtra (Western Region), plant availability increased by about 2% for every 1% reduction in AC. The Satpura trials showed even more startling results --plant availability increased by 3% for every 1% reduction in AC. However, we assume a conservative estimate of a 1% increase in availability for every 1% reduction in ash content, as claimed in the US (See Meier and Thukral, 1990).

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**Economic Analysis of alternative strategies**

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**Introduction**

In this chapter, costs associated with various development strategies to the year 2009/10 are presented. These include: (i) direct economic costs associated with the production and supply of various energy sources; (ii) direct measures; and (iii) environmental costs associated with energy supply and demand management. Thus the model uses an "expanded" economic approach since in the evaluation of strategies, costs include capital and operating costs and the costs of some environmental and social impacts of energy choices.

Levelized annual cost approach is used to determine economic costs. Capital costs used for various energy supply and demand management measures are based on normative capital investment levels. Although the actual phasing of investment is not accommodated for in the economic analysis, gestation periods are used to compute interest during construction at a 12% discount rate. The capital costs are then annuitized over the economic lifetime of these assets. Operating and maintenance costs are assumed as a percentage of capital costs. The planning time horizon is 1990-2010. The discount rate used is 12% but other discount rates can be easily accommodated. All costs are in 1990/91 prices and the exchange rate assumed in US\$1 = Rs.18 (average for 1990/91).

Energy supply measures for the following sectors have been costed: Coal, oil, natural gas, hydropower, nuclear power, energy conservation, renewable options such as windfarms and small hydel projects. Shortages of oil and coal are valued at border prices as these would need to be imported. Lower bound estimates of the value of power shortages are obtained by estimating the costs involved in having standby generation. Energy savings from conservation measures are valued at border prices wherever this results in a change in the net fuel imports and at economic prices where they are not. Depletion premiums have not been estimated.

Environmental costing employed indirect techniques involving the use of control costs (or cost of damage abatement approach), cost of damage approach, and the use of reclamation costs and rehabilitation costs. Environmental impacts associated with TSPs, nitrogen oxides and sulphur oxide emissions from coal based thermal power plants are monetized using control costs. Impacts on forests from submergence by hydropower projects and from clearing for coal and lignite mining projects are valued by assessing the cost of the forest area lost in terms of its environmental services and economic goods. Environmental costs of land affected by overburden dumps from coal mining projects are valued using the cost of reclaiming this land. Social costs of displacing people on account of coal mining projects are given a lower bound value by assessing the cost of rehabilitating them. Costs are monetized using various discount rates - 3, 5, 7, 10 and 12 percent.

In addition to these costs at the national/regional level, economic and environmental costs in two areas of stress (Singrauli and Delhi) are also presented.

In evaluating the BAU strategy demand side investments are used as reference level and only supply side investments are considered. For the alternative strategies, incremental investment requirements for supply and energy demand measures over the BAU strategy are taken into account.

## **7.2 Assumptions**

### **7.2.1 Demand side**

The demand side investments for the BAU strategy are chosen as the reference level, and therefore only incremental investments for the set of demand management measures that comprise the alternative strategies are included. Some general assumptions for the economic analysis are as follows:

In the domestic sector, the comparative economic analysis of fluorescents and incandescents is carried out by taking the average market price of installing the two types of connections. The price of each of the component parts and its operating life is given in Table 7.1. The cost of electricity is taken to be US\$ 0.08/kWh.

For improved refrigerators, the market prices of the old and new models of refrigerators are taken as US\$ 333 and US\$ 417 respectively, with the mean operating life of 20 years. In case of both the models, annual maintenance costs are assumed to be 1 per cent of the capital cost.

**Table 7.1.** Assumptions regarding the market price and operating life of fluorescent and incandescents.

	Market price (US\$/unit)	Operating life (years)
Fluorescents		
- Holder	2.20	15
- Tube	1.95	2 <sup>(1)</sup>
- Choke	4.20	5
Incandescents		
- Holder	1.70	10
- Bulb	0.50	0.4 <sup>(1)</sup>

(1) These are estimated by assuming the average life of a fluorescent lamp to be 5000 hours, incandescent bulb as 1000 hours and the average daily use to be about 7 hours.

For the option of a portion of urban residential cooking energy demand to be met by solar cookers, it is assumed that the solar cookers would substitute only 20% of the energy demand for cooking in the owner households. This is because a solar cooker is not a perfect substitute for conventional cooking devices owing to its unsuitability for frying or making chappatis (Indian wheat bread) which are essential components of an Indian meal. The capital cost is assumed to be US\$ 60 as against its market price which is much lower due to the subsidy offered by the Government. The annual O&M is taken as 2.5% of the capital and an average operating life of 10 years.

For the combined option of using biogas with improved cookstoves, the cost of construction of a family size biogas plant (2m<sup>3</sup> capacity) is taken to be US\$ 278 and that of an improved cookstove to be US\$ 3.9, with O&M costs of 0.5% and 0.67% of capital respectively. The life of a biogas plant is assumed to be 20 years and an improved cookstove to be 5 years.

In the transport sector, all existing buses are assumed to be phased out with the introduction of urban buses. The additional capital cost is taken as US\$ 0.5 million, O&M at 5 per cent of the capital and a life of 20 years.

For road improvements, the investments are phased out at the rate of 40%, 30%, 20% and 10% of a total of US\$ 8.7

billion for the years 1994/95, 1999/00, 2004/05 and 2009/10 respectively. O&M costs are assumed at 5 per cent of the capital cost.

For the shift from road to rail option, the investment (US\$ 50 billion) is assumed to be phased similar to the strategy of road improvements. The life of the system is assumed to be 35 years and O&M cost at 2.5 per cent.

The net investment required is derived after deducting the investment removed from the road sector (swing effect) from the gross investment in railways.

The metro option has an average investment of US\$ 1.3 billion each, the phasing of which is similar to the strategy of road improvements. Interest during construction (IDC) has been included at 12%. It is assumed that metro systems start functioning from the year 2000/01 and hence the swing effect i.e. shift from road transport modes to metro will be observed only after 2000/01. Based on the pkm the metro system would satisfy, it is assumed that it would displace 10% of cars, 10% of three wheelers, 45% of two wheelers and 35% of buses in each of the cities. The life of the system is assumed to be 35 years and O&M costs are placed at 5% of the capital cost. The fuel consumption of the metro system is assumed to be 9 watt-hours per pkm [8kCal/pkm (30kCal/pkm taking in to account the generation and T&D efficiencies)] as against 92kCal/pkm for a bus.

The assumptions made for the CNG option is that the O&M costs are 10 per cent of the capital cost and average life of the system is 35 years.

In the industrial sector, conservation measures are considered for the iron and steel, petrochemicals and cement industries. O&M costs for process changes are assumed to be 2.5% of the capital. Life time of equipment is taken as 20 years.

The assumptions in the agricultural sector are as follows. The cost of replacing footvalve and suction pipeline is \$32 (\$46 with delivery line included) per pump-set. The life of both the options is 5 years.

The cost of replacing the pump is assumed to be \$152 and has a life of 7 years. The cost of replacing the motor is \$380 and has a life of 15 years.

#### 7.2.2 Supply side

The basic objective is to compute both capital costs of investing in various supply projects during the 1990/91

through 2009/10 period (which may be annuitized over their economic life times) plus fixed and variable operating costs incurred in the year 2009/10. Net fuel import bills are also included.

Various types of power generating capacity and other energy supply establishments have gestation periods of several years during which the investment is made. Although the actual phasing of investment is not accounted for in the economic analysis, the gestation periods are used to compute the interest during construction (IDC) at a social discount rate of 12% per annum. Further, the capital costs are annuitized over the economic lifetimes of these assets. Table 7.2 lists the gestation periods, IDC factors, economic life times and capital recovery factors (CRF) for various energy supply infrastructure requirements.

**Table 7.2.** IDC factors\* and CRF for energy supply infrastru

	Gestation period (years)	IDC factor*	Economic life (years)	CRF
<b>Power Plant</b>				
- Hydro	8	1.5036	50	0.120
- TPS	6	1.3382	30	0.124
- GT/CCP	3	1.1236	30	0.124
- Nuclear	12	1.8983	30	0.124
- Windfarms	1	1.0	20	0.133
- Small Hydro	1	1.0	30	0.124
<b>Refinery</b>				
- with FCC	6	1.3382	30	0.124
- with HCU	6	1.3382	30	0.124
LPG Extraction	2	1.06	30	0.124
<b>Coal Mining</b>				
- OC	5	1.2625	35	0.122
- UG	8	1.5036	35	0.122
<b>Gas Pipelines</b>				
- On land	2	1.06	30	0.124
- Offshore	2	1.06	30	0.124

\* Ratio of IDC plus capital investment to capital investment.

Fixed O&M costs (as a percentage of capital investment plus IDC) are assumed as follows : (i) 1% for large hydro projects; (ii) 2.5% for coal based TPS units, using both washed and unwashed coals; (iii) 2% for GT/CCP units; (iv) 2.5% for nuclear power stations; (v) 3.33% for windfarms; (vi) 2% for small hydro projects; (vii) 5% for LPG extraction plants; (viii) 7.5% for natural gas pipelines, both onland and offshore; and (ix) 10% for exploratory drilling and oil/gas field developmental activities. The O&M costs of refineries with FCC units are taken at \$4870/tonne of crude feed, and for those with HC units at \$15400/tonne of crude feed. Likewise, open-cast and underground coal/lignite mining projects are assumed to entail a cost of \$7.4/tonne and \$14.1/tonne of output respectively.

Owing to the fact that there will be significant shortages of coal and oil, foreign exchange requirements for fuel imports are also estimated. The following assumptions are made: (i) border prices of coal and crude oil are the same in calorific value terms; (ii) border price of crude oil as \$20/barrel in 1990/91; (iii) border price of fuel oils and bitumens as \$18/barrel in 1990/91; (iv) border prices of other refined products (motor-spirits, naphtha, diesel oils, kerosenes etc.) were \$22/barrel in 1990/91; and (v) prices of crude oils and refined products increase in real terms to the year 2009/10, at the rate of 1% per annum.

For computing costs of supplying coal and fuel oil to power stations in various regions, the average distances for transportation by railways and associated cost of freight transport per tonne of fuel (as obtained from the Railway Board) are given in Table 7.3. As fuel oils will be imported at the margin, the distances are as measured from the port of import. For coal and lignite transportation, distances from mines are considered. Natural gas costs for power generation are assumed to be at par with fuel oil costs (in calorific value terms) in each Region.

For nuclear power stations, annual make-up of heavy water and natural uranium are taken at 34 kg/MW and 140 kg/MW of installed capacity respectively; and their costs at \$1335/kg and \$204/kg respectively.

It is assumed that various types of consumers will install and use standby dg (diesel generator) sets to mitigate the effects of power shortages. The costs of dg sets are as follows: (i) capital cost plus installation charges of \$350/kW; (ii) fixed annual costs (including salaries/wages

and maintenance charges) of \$44.6/kW; and (iii) diesel and lubricating oil consumption at the rates of 0.3 litres/kWh and 0.006 litres/kWh respectively.

The economic life time of dg sets is taken as 15 years, and capacity utilization at 500 kWh/kW per annum. For sake of convenience, only the border prices of diesel and lubricating oils are considered -- an implicit assumption being that grid power is traded between regions and shortages arise largely in the coastal areas. Costs incurred in using dg sets give the lower bound estimates of costs of power shortages.

In addition to the assumptions listed above, the capital investment requirement norms for various types of energy supply projects, as given in Chapters 3 and 4, are used for computing economic costs for various development strategies.

**Table 7.3.** Fuel transportation costs to TPS units in various regions

	Coal/Lignite		Fuel Oil	
	Distance (km)	Transportation Costs (\$/tonne)	Distance km)	Transportation Costs (\$/tonne)
NR	550	38.87	1000	44.60
WR	400	28.27	200	10.01
SR	300	21.20	400	18.20
ER	150	10.60	300	14.18
NER	200	14.10	100	5.88

### BAU strategy

Owing to the fact that the demand side investments in the BAU strategy are made as the reference level, only supply side investments are presented below.

Economic costs associated with the BAU strategy, under both 5% and 6% per annum GDP growth assumptions, are summarized in Table 7.4. Total costs are estimated at \$176.6 billion and \$204.3 billion respectively. Costs in the high GDP growth case are higher by about 15.7% over the lower GDP growth rate case.

The major cost components in the low GDP growth case are power supply (55.3%), hydrocarbon exploration and field development (18.8%), and fuel imports (13.2%). The cost shares of these components are very similar in the high GDP growth case, at 53.9%, 17.1% and 15.9% respectively. The share of the fuel import bill rises in the latter case



essentially because indigenous coal and lignite production remain the same as in the former. As net imports of middle-distillates account for over 43% of the fuel import bill in the low GDP growth case, and over 37% in the high GDP growth case, the need to curtail their demand is reiterated.

The region-wise break-up of economic costs are given in Appendices 7.1 and 7.2 for the low and high GDP growth rate cases respectively. The largest share of the costs are incurred in the Western Region, due largely to the high share of oil/gas exploration and development activity there. Costs are least in the Northeastern region, and reflect the low levels of energy requirements there.

Costs incurred directly in foreign exchange (for fuel imports alone) are anticipated to rise to \$23.2 billion in the low GDP growth case and \$32.4 billion in the high GDP growth case. In comparison, the net fuel import bill in 1989/90 (the most recent year for which reliable data are available), was less than \$3.3 billion; and total imports were only \$20.8 billion. The rapid rise in foreign exchange requirements for fuel imports indicates the need to pursue alternative development strategies.

**Table 7.4.** Economic costs of energy supply in the BAU strategy (\$ million, 90/91 prices)

	Low GDP Growth Case	High GDP Growth
Total	176622	204275
Coal mining	10809	10809
Lignite mining	671	671
Hydrocarbon exploration	27645	29023
Hydrocarbon field development	5477	5963
Refining	2729	2729
LPG extraction	220	289
Natural gas pipelines		
- on land	1932	2219
- offshore	1362	1624
Power supply	97682	110039
Power shortages	4847	8480
Net fuel imports	23248	32429
- Coal	2295	11827
- Crude oil	9375	6678
- Refined products	11578	13924

## Alternative strategies

### Demand side

#### 1.1 Alternative strategy I

##### Domestic sector

Energy efficient lighting: Table 7.5 gives the incremental annual costs (inclusive of fuel costs) both in aggregate and per household terms, and the associated electricity savings achieved by replacing incandescent bulbs with fluorescent lamps in the year 2009-10.

**Table 7.5.** Economic analysis of energy efficient lighting

Region	Net Annual Savings (million US\$)	Annual savings per household (US\$)	Annual electricity savings (TWh)
<b>5 % GDP growth rate</b>			
North	126.38	5.48	1.46
South	20.64	1.01	0.18
West	70.62	3.83	0.82
East	26.69	2.32	0.32
North-east	5.82	2.97	0.07
All India	250.15		2.85
<b>6 % GDP growth rate</b>			
North	88.33	4.06	1.02
South	16.57	0.86	0.15
West	103.14	5.93	1.2
East	22.52	2.08	0.27
North-east	4.99	2.70	0.06
All India	235.55		2.7

The results clearly indicate that owing to a longer life and greater luminous efficacy fluorescents would result in substantial savings, both in terms of costs as well as energy. These get translated to annual financial savings varying in the range of US\$ 1 to US\$ 6/household in different regions of the country. Moreover, the savings in capital that would accrue from this measure are estimated to be of

the order of US\$ 71 million (5% GDP growth rate) and US\$ 70 million (6% GDP growth rate).

**Improved refrigerators:** For domestic refrigerators, the analysis of economic viability of new and more energy efficient models has been carried out by assuming that these would replace at least 25% of the total stock in the long run, beginning 1999-2000. In the preceding period, from 1989-90 to 1999-2000, about 30% conservation in energy would be achievable through regular maintenance and defrosting.

Table 7.6 shows the annual financial and electricity savings in the year 2009-10 brought out by partial replacement of the remaining stock.

The analysis here closely follows the methodology adopted for energy efficient lighting measures.

**Table 7.6.** Economic analysis of improved refrigerators

Region	Net Annual Savings (million US\$)	Annual savings per household	Annual electricity savings (TWh)
<b>5 % GDP growth rate</b>			
North	111.17	4.82	1.850
South	113.19	5.56	1.710
West	35.75	1.94	0.530
East	23.57	2.05	0.350
North-east	4.84	2.47	0.070
All India	288.53		4.510
<b>6 % GDP growth rate</b>			
North	111.79	5.14	1.860
South	113.13	5.89	1.710
West	35.73	2.06	0.530
East	24.32	2.24	0.360
North-east	4.03	2.18	0.060
All India	289.00		4.520

The net investments associated with each option amounts to US\$ 72.3 million (5% GDP growth rate) and US\$ 72.6 million (6% GDP growth rate).

The analysis clearly shows the economic viability for both the options.

## Transport sector

Table 7.7 gives the fuel savings and cost per kgoe of energy saved for each of the four above options in the year 2009/10. As compared to these figures, the economic cost of energy supply is far higher. In addition to the fuel saving that these options provide, they also have substantial other benefits like release of congestion in urban areas, improvement in the life of engine and reduced demand for spare parts etc.

Of the options mentioned, metro system would generate substantial savings, both in terms of cost and fuel but this option requires substantial initial investment in the order of US\$ 11 billion (total for the nine cities considered) during the first 10 years.

Large amount of fuel saving is also possible in the option of modal shift (road to rail).

**Table 7.7.** Annualised cost per unit of energy saved in the transport sector

	5% growth rate		6% growth rate	
	Fuel saving (mtoe)	\$/ (kgoe saved)	Fuel saving (mtoe)	\$/ (kgoe saved)
<b>Urban buses</b>				
North	1.051	0.115	1.115	0.115
South	0.919	0.115	0.964	0.115
West	0.903	0.115	0.969	0.115
East	0.238	0.115	0.253	0.115
North-East	0.185	0.115	0.196	0.115
All India	3.297	0.115	3.497	0.115
<b>Road improvements</b>				
North	2.795	0.114	3.140	0.162
South	1.677	0.121	1.852	0.173
West	1.837	0.118	2.058	0.168
East	1.528	0.121	1.639	0.173
North-East	0.268	0.127	0.293	0.180
All India	8.107	0.118	9.520	0.159

CONTD..

**Table 7.7. Contd...**

	5% growth rate		6% growth rate	
	Fuel saving (mtoe)	\$/ (kgoe saved)	Fuel saving (mtoe)	\$/ (kgoe saved)
Shift from road to rail				
North	4.617	0.072	5689	0.046
South	2.419	0.073	2.980	0.047
West	2.837	0.075	3.496	0.048
East	1.826	0.071	2.250	0.045
North-East	0.393	0.066	0.484	0.047
All India	12.091	0.072	14.899	0.047
Metro system				
North	0.811	-0.108	0.811	-0.108
South	0.811	-0.108	0.811	-0.108
West	0.532	-0.108	0.811	-0.108
East	0.566	-0.101	0.566	-0.101
North-East	0.000	0.000	0.000	0.000
All India	2.719	-0.106	2.719	-0.106

Note: - implies overall investment savings over BAU (see text for details)

To sum up, all the above four options are economically justifiable.

#### **Industrial sector**

Table 7.8 gives the cost per unit of energy saved for the three industries in the year 2009-10. As compared to these estimates, the economic cost of energy supply ranges from 0.2 to 0.33/kgoe thus establishing the economic viability of the energy conservation measures outlined in Chapter 6.

**Table 7.8.** Annualised cost per unit of energy savings in the industrial sector

Region	Cost (US\$/kgoe)		
	Iron & steel	Chemicals & petro-chemicals	Cement
<b>5 per cent GDP growth rate</b>			
North	0.11	0.12	0.03
South	0.11	0.12	0.03
West	0.11	0.12	0.03
East	0.11	0.17*	0.03
North-East	0.0	0.12	0.03
All India	0.11	0.12	0.03
<b>6 per cent GDP growth rate</b>			
North	0.11	0.12	0.03
South	0.11	0.12	0.03
West	0.11	0.12	0.03
East	0.11	0.17	0.03
North-East	0.0	0.12	0.03
All India	0.11	0.12	0.03

\* In the Eastern region petrochemical industry is entirely naphtha based which has higher energy consumption compared to natural gas based plants.

The incremental annualised investment for the three industrial sub-sectors put together was worked out to be US\$ 1751.22 and 1766.45 for the 5 per cent and 6 per cent rates of growth of GDP scenarios.

### **Agricultural sector**

Table 7.9 shows the costs incurred per unit of energy saved for measures in the agricultural sector. As can be seen retrofitting of pumps is an extremely viable option. The total costs per energy saved of all measures (retrofitting of pumps and penetration of drip and sprinkler systems) is far higher than the cost of supplying energy. This is because the drip system has high capital intensity and is essentially a water conserving option. This option is considered largely due to growing concerns regarding the sustainability of tapping groundwater for irrigation purposes.

**Table 7.9.** Annualized cost per unit of energy saved in the Agriculture sector (\$/kgoe)

	I	II
North	0.030	0.47
West	0.030	0.24
South	0.032	0.54
East	0.027	0.10
All India	0.030	0.39
I - Retrofitting of pumps II - Retrofitting of pumps and penetration of drip and sprinkler systems		

#### 7.4.1.2 Alternative strategy II

##### **Domestic sector**

Solar cookers: In this case, the option of a portion of urban residential cooking energy demand to be met by solar cookers was analysed.

The output of the economic analysis of solar cookers for meeting a part of domestic cooking energy demand is presented in Table 7.10, which gives the cost per unit of LPG saved.

As against specific costs tabulated above the economic cost of LPG was worked out to be about US\$ 0.48/kg - US\$ 0.6/kg thus making solar cookers a viable option in some regions of the country.

The annualised incremental investments of this option are worked to be US\$ 105 million and US\$ 100 million in case of the two scenarios of 5 per cent and 6 per cent GDP growth rate.

**Table 7.10.** Cost per unit of LPG saved through the use of solar cookers

Region	Cost of solar cooker (US\$/Kg of LPG saved)
<b>5 % GDP growth rate</b>	
North	0.47
South	0.41
West	0.50
East	0.46
North-east	0.62
All India	0.46

Table 7.10. Contd..

Region	Cost of solar cooker (US\$/Kg of LPG saved)
<b>6 % GDP growth rate</b>	
North	0.44
South	0.39
West	0.47
East	0.44
North-east	0.58
All India	0.43

Biogas plants and improved cookstoves: The economic analysis of biogas to meet domestic energy demand in rural areas was carried out by taking the annualised cost of the stock of biogas plants and improved cookstoves in the year 2010 and the associated savings in firewood. The results of the analysis presented in Table 7.11 below give the annualised cost per unit of firewood saved. These costs which average at US\$ 0.016/kg of firewood at the national level are much lower than the economic cost of supply of fuelwood.

Table 7.11. Economic analysis of Biogas plants

	Annualised Cost (US\$/Kg of firewood saved)	Annual firewood savings (Mt)
North	0.0169	3.27
South	0.0148	4.24
West	0.0188	5.89
East	0.0129	2.44
North-East	0.0045	0.62
All India	0.0160	16.46

The additional annualised costs of investing in this option are worked to be about US\$ 375.4 million by the year 2010.



Table 7.12 shows the total fuel savings and cost per kgoe of fuel saved. The cost per unit of fuel saved (\$ /kgoe) range from 0.064 to 0.071 which is far below the economic cost of supply.

**Table 7.12.** Fuel savings and cost per unit of fuel saved.

	Total savings (mtoe)	Cost per 2009-10 (\$/kgoe saved)
North	1.71	0.065
West	0.92	0.064
South	0.25	0.068
East	0.25	0.068
North-east	0.12	0.071
All India	3.24	0.068

Table 7.13 gives the annualised incremental costs over BAU for alternative strategies for the year 2010.

**Table 7.13.** Annualised incremental requirements for alternative strategies (million US\$)

	Domestic sector		Industrial sector		Transport sector		Agricultural sector <sup>1</sup>		Total	
	5%	6%	5%	6%	5%	6%	5%	6%	5%	6%
<b>Alternative strategy I</b>										
North	9.16	9.17	42.41	49.57	684.1	813.8	1091.1	1524.5	1826.77	2397.04
West	-10.01 <sup>2</sup>	-8.63 <sup>2</sup>	359.15	371.58	475.8	567.1	269.8	377.0	1094.74	1307.05
South	1.41	1.52	531.27	527.76	399.1	483.5	469.0	655.3	1400.78	1668.08
East	0.60	0.66	814.59	814.59	283.3	357.6	58.9	82.4	1157.39	1255.25
North-East	-0.03	-0.02	5.35	4.49	81.1	95.7	-	-	86.42	100.21
All India	1.14	2.70	1752.77	1767.99	1923.4	231.7	1888.8	2639.2	5566.10	6727.63
<b>Alternative strategy II</b>										
North	31.77	30.37	-	-	111.72	111.72	-	-	142.94	141.54
West	25.78	24.65	-	-	58.76	58.76	-	-	84.43	83.30
South	28.80	27.56	-	-	16.63	16.63	-	-	45.34	44.10
East	15.96	15.25	-	-	16.63	16.63	-	-	32.50	31.79
North-East	2.61	2.50	-	-	8.78	8.78	-	-	11.30	11.19
All India	104.92	100.33	-	-	212.53	212.53	-	-	316.50	311.91

Cost figures include drip and sprinkler irrigation systems (essentially water conserving measures) comprising 5% of the costs and retrofitting pumps which comprise the remaining 5% of the costs.

Net incremental investment savings.

4.1.3 Combination strategy: In this strategy, where both energy conservation measures (as in Alternative Strategy I) and use of alternative energy sources (as in Alternative Strategy II) are considered, the costs incurred on the demand side are obtained simply by summing up the costs given in Table 7.13.

#### 4.2 Supply side

In alternative strategy I, where washing of non-coking coals for use in TPS units, and T&D loss reduction are the major measures to enhance the efficiency of the energy supply industry, the total economic costs are estimated at \$139.9 billion in the low GDP growth case, and \$159.8 billion in the high GDP growth case. These costs imply a reduction by 20.8% and 21.8% from the corresponding BAU levels. This substantial reduction is due also to the fact that energy conservation measures are affected on the demand side -- which in turn reduces the need to invest in energy supply projects.

**Table 7.14.** Changes in economic costs of energy supply in the alternative strategies (5% per annum GDP growth case)

	Alternative strategy I	Alternative strategy II	Combination strategy
<b>Percent reduction from BAU strategy</b>			
Total	20.8	-0.3	21.0
Hydrocarbon field development	0.05	-0.01	0.05
Natural gas pipelines			
- on land	0.2	-11.0	-10.8
- offshore	0.15	-8.2	-8.1
Power supply	17.2	-0.3	16.9
Power shortages	53.4	4.3	69.7
Net fuel imports	74.8	3.9	75.4
- Coal	366.6	0	366.6
- Crude oil	0	0	0
- Refined products	77.5	7.9	78.8
<b>Memo item</b>			
Total costs (\$ million)	139904	176114	139577
Coal washing			
Costs (\$ million)	36.8	0	36.8

**Note:** Coal washing is treated as a a production cost of energy supply and not as an environmental cost.

In alternative strategy II, where the only supply side changes are for enhancing RET based power generating capacity (windfarms and small hydro units), the costs for supplying energy supply (inclusive of shortage cost) decreases from BAU levels. In the low growth case, total costs are estimated at \$176.1 billion (a decrease of 0.3% from the BAU level), and in the high growth case at \$203.8 billion (a decrease of 0.2% from the BAU level).

**Table 7.15.** Changes in economic costs of energy supply in the alternative strategies (6% per annum GDP growth case)

	Alternative strategy I	Alternative strategy II	Combination strategy
<b>Percent reduction from BAU strategy</b>			
Total	21.8	0.2	22.0
Hydrocarbon field development	0.03	-0.01	0.03
Natural gas pipelines			
- on land	7.2	-9.6	-2.4
- offshore	5.5	-7.3	-1.8
Power supply	17.9	-0.3	17.8
Power shortages	84.4	2.2	84.6
Net fuel imports	53.6	2.8	56.4
- Coal	70.4	0	70.4
- Crude oil	0	0	0
- Refined products	65.1	6.6	71.7
<b>Memo item</b>			
Total costs (\$ million)	159824	203783	159317
Coal washing			
Costs (\$ million)	49.8	0	49.8

**Note:** Coal washing is treated as a a production cost of energy supply and not as an environmental cost.

In the combination strategy, where both efficiency enhancement measures and alternative energy supply options are considered simultaneously, the total costs reduce substantially from BAU levels -- by 21.0% in the low growth case and 22.0% in the high growth case.

Similar changes in costs across strategies are also evident at the regional level (see Appendices 7.1 and 7.2 for the low and high growth cases respectively). As for the BAU

strategy, the largest share of costs are incurred in the Western Region, and the least in the Northeastern region.

Although coal and lignite production and their costs, as well as hydrocarbon exploration levels, remain the same across various strategies for a particular GDP growth rate, oil/gas field development and gas pipeline costs change marginally (see Tables 7.14 and 7.15). This reflects the difference in free gas production levels (in line with total gas demand) between the various strategies.

Power supply costs reduce in strategy I from BAU levels (since smaller capacity additions are required). They also reduce in strategy II (the benefits obtained in the form of a reduction in energy shortages outweigh the increase in additional RET capacity costs). The combination strategy therefore results in the largest reduction in power system costs.

Perhaps the greatest differences are observed with regard to net fuel import bills. In strategy I, the reduction of foreign exchange requirements for fuel imports are substantial -- by about 75% from the BAU level in the low growth case, and by nearly 54% in the high growth case. The net fuel import bill reduces to \$5.9 billion in the low growth case, and \$15 billion in the high growth case. Fuel import bills in strategy II also reduce somewhat from BAU levels, but the change is only marginal. The relative effects on the net fuel import bills clearly indicates the need to implement conservation measures both on energy supply and demand sides. Tables 7.14 and 7.15 also show that net fuel import bills further reduce in the combination strategy, but fall only marginally below those in strategy I.

#### **Valuing environmental impacts/damage from energy production and use**

Indirect techniques were employed involving the use of two approaches - preventive expenditures and change in productivity to value environmental impacts from energy production and use. Paucity of data on environmental impacts both at a site specific level as well as over regions as wide as those defined in this study made it difficult to place a monetary value on such impacts. Thus, this exercise has been limited to valuing the environmental impacts of air pollution, namely total suspended particulates (TSPs) and

oxides of nitrogen (NO<sub>x</sub>), and forest lost due to submergence from hydroprojects and coal mining.

#### 7.5.1 Discount rates used

The social discount rate for this part of the study was calculated using the standard formula for discounting future consumption:

$S = C + e + p$  where

C = rate of growth of per capita real consumption

e = elasticity of marginal utility of consumption

p = rate of pure time preference

An assumption is made of constant elasticity of the marginal utility of consumption to be 2 which is commonly found in empirical work. We take the position that on ethical grounds (i.e. equality across generations) there can be no discounting of utility over time periods, so time preference rate is zero. Rate of growth of per capita real private consumption over the period 1980-81 to 1989-90 was 2.7% (CMIE, 1991). Taking the past growth rate as a guide, C is set at 2.7% and accordingly, S works out at 5.4%. This is rounded off to 5% as the margin of error so introduced would be negligible.

A sensitivity analysis using discount rates of 3%, 5%, 7%, 10% and 12% is carried out to assess the implications of different discount rates on the costs estimated.

#### 7.5.2 Air quality

The indicators of air quality that are valued here are total suspended particulates (TSPs), oxides of nitrogen (NO<sub>x</sub>) and sulphur dioxide (SO<sub>2</sub>). Environmental damage due to each pollutant from power plants is estimated by region and pollution control costs are used as a proxy for damage avoidance cost or a damage abatement approach, to obtain a lower bound value for damages (Shulz and Shulz, 1991). The expenditure which is accepted (or not accepted) for environmental protection (e.g. electrostatic precipitators (ESPs) for control of TSPs) is taken as an indication of what society is willing to pay for a reduction in pollution. Thus if these devices are actually installed, one can assume that willingness to pay is greater than or at least equal to the cost of abatement. The study should have attempted to obtain an independent estimate of willingness to pay since these would enable us to address the question whether society should pay for abatement. This exercise is however, much

more complicated and beyond the scope of this study and so an assumption is made that the willingness to accept (or not accept) abatement costs is an indication of the willingness to pay to avoid pollution. For example, the cost per unit pollutant removed is the amount society is willing to pay to avoid the damage caused by that unit pollutant. The resulting improvement is worth at least that much to society.

Estimating the cost per unit pollutant removed involves the following stages (Baasel, 1985):

- (1) Calculation of (pollutant) emissions per unit production with no controls in place.
- (2) Estimation of pollutant emissions per unit production using control equipment, e.g. electrostatic precipitators used to control TSP emissions from power plants.
- (3) Estimation of pollutant reduction per unit production.
- (4) Calculating the levelized annual control costs per unit production and costs per unit pollutant removed. This latter value is used to place a lower bound on environmental damage (except perhaps relating to sulphur dioxide emission control) caused by these pollutants and is the figure used to value estimated emissions of the particular pollutant in each energy region from power plants projected to come up between 1990 and 2010.

It is currently mandatory to install ESPs in new power plants, and therefore this approach gives a fair idea of the magnitude of the damage caused by TSP. However, both  $\text{SO}_x$  and  $\text{NO}_x$  control is currently not mandatory and in most cases the control technologies used to evaluate the damage costs will not be implemented.

### .3 Business-as-usual strategy

- .3.1 Particulate emission: Table 7.16 provide a summary of the minimum cost of environmental damage from TSP emissions from power plants by energy region for a 5% and 6% GDP growth rate at various discount rates. The cost per unit of TSP removed ranges between 0.18 cents/kg at a 3% discount rate, 0.22 cents/kg at a 5% discount rate to about 0.37 cents/kg at a 12% discount rate. The pollution (TSP) cost per unit of electricity generated ranges between 0.038 cents/kWh at 3%

discount rate, 0.046 cents/kWh at a 5% discount rate and 0.078 cents/kWh at a 12% discount rate. This implies that if no ESPs were installed, the total economic costs of generating electricity would have to be increased by at least these amounts to reflect pollutant costs, if a total cost approach is to be adopted\*.

**Table 7.16.** Total environmental damage from TSPs from coal based thermal power plants for the period 1990-2010\*  
( '000\$, 1990/91 prices)

Region	3%	5%	7%	10%	12%
<b>5% GDP growth rate</b>					
North	84.68	101.41	119.94	150.33	171.87
West	78.81	94.39	111.63	139.92	159.96
South	70.35	84.24	99.63	124.88	142.78
East	79.92	95.71	113.19	141.88	162.20
North-east	n.a.	n.a.	n.a.	n.a.	n.a.
All India	313.76	375.75	444.38	557.01	636.82
<b>6% GDP growth rate</b>					
North	100.80	120.72	142.77	178.95	204.59
West	91.85	110.00	130.09	163.06	186.43
South	84.58	101.30	119.80	150.16	171.68
East	94.59	113.28	133.97	167.92	191.98
North-East	n.a.	n.a.	n.a.	n.a.	n.a.
All India	371.83	445.30	526.64	660.11	754.69

- \* The assumptions made to arrive at these values are:
- (i) The costs of ESPs vary between \$ 3.9-5 million for a 210 MW plant and between \$ 8.4-11.1 million for a 500 MW plant, depending on the efficiency of removal required. Assuming a removal efficiency of 99.8%, the per unit cost of the ESP has been computed using the upper values as an average of the 210 and 500 MW plants i.e.  $(5+11.1)/710$  million \$/MW. [Source: Unpublished data, M. Kirorimal, Manager Commercial, ESP projects, BHEL]
  - (ii) Life of an ESP is assumed to be 30 years and O&M costs to be 2% of total capital costs.
  - (iii) The conversion of capacity to generation has been carried out on the assumption of an all India average plant utilization of 4900 hours of generation.
  - (iv) It is assumed that 0.65 kg coal is consumed per kWh electricity generation.

\* Economic LRMC of generating electricity ranges between 1.01 to 4.06 cents/kWh (see TERI, 1991).

(v) Estimation of uncontrolled emissions of TSPs are based on the work of T.T. Shen (1980) where it is estimated that TSP emissions are 0.8 times the weight of ash in coal (which is 40% for Indian coals used in power plants).

3.2 NO<sub>x</sub> emissions: An identical exercise (as for TSPs) is carried out for NO<sub>x</sub> emissions in the country. Table 7.17 provide a summary of the lower bound of the cost of environmental damage (as measured by its control cost) from NO<sub>x</sub> emissions from thermal power plants by energy region for a 5% and 6% GDP growth rate at various discount rates using selective catalytic reduction (SCR) techniques. The cost per unit NO<sub>x</sub> removed ranges from \$ 1.18/kg at a 3% discount rate to \$ 1.20/kg at 5% and \$ 1.30/kg at a 12% discount rate. The pollution (NO<sub>x</sub>) cost per unit electricity generated ranges between 0.69 cents/kWh at a 3% discount rate and 0.76 cents/kWh at a 12% discount rate. This implies that were there no SCRs installed, the total economic costs of generating electricity would have to be increased by the same amount to reflect pollution costs, if a total cost approach is adopted. The levelized annual costs of NO<sub>x</sub> control range from 0.59 cents/kWh at 3% discount to 0.60 cents/kWh at 5% and 0.65 cents/kWh at 12% discount rate.

**Table 7.17.** Total environmental damage from NO<sub>x</sub> from coal based Thermal power plant (1990-2010)\*  
( \$ million; 1990/91 prices)

Region	3%	5%	7%	10%	12%
<b>5% GDP growth rate</b>					
North	109.94	112.3	114.91	119.19	122.22
West	103.61	105.80	108.23	112.21	115.04
South	91.71	93.67	95.84	99.39	101.91
East	106.61	108.83	111.29	115.33	118.19
North-east	n.a.	n.a.	n.a.	n.a.	n.a.
All India	411.87	420.6	430.26	446.12	457.36
<b>6% GDP growth rate</b>					
North	130.32	133.13	136.23	141.33	144.94
West	120.12	122.68	125.51	130.15	133.44
South	109.69	112.04	114.65	118.92	121.95
East	125.15	127.79	130.70	135.48	138.87
North-East	n.a.	n.a.	n.a.	n.a.	n.a.
All India	485.29	495.64	507.09	525.88	539.20



The assumptions made to arrive at these vales are:

- (1) Capital costs of SCR assumed at \$36.425/MW installed capacity and O&M costs at \$ 0.054/kWh generated.
- (2) Life of an SCR assumed to be 30 years.
- (3) Removal efficiency assumed to be 85%.
- (4) Estimation of uncontrolled emissiions are based on the work of T.T. Shen (1980).

.5.3.3 Sulphur oxide emissions: An exercise was also carried out to examine the merits of installing flue gas desulphurizers (FGDs) in the Indian context. As the sulphur content of most Indian coals generally varies between 0.3-0.5%, FGD scrubbers are of limited use. However, certain regions in India have coals with a high sulphur content, for example, Assam coal has a sulphur content of 3%. In the future, FGD techniques may find limited application either in the Singrauli region (should capacity expansion occur at the pace planned) or in metropolisis like Delhi where the environment is already stressed.

The levelized annual cost of FGD and the cost per unit SO<sub>2</sub> removed are given in Tables 7.18 and 7.19 respectively.

**Table 7.18.** Cost per unit pollutant (SO<sub>x</sub>) removed (\$/kg, 1990/91 prices)

Sulphur content in coal (%)	Discount rates				
	3%	5%	7%	10%	12%
0.5	3.54	3.62	3.71	3.86	3.97
1.0	1.77	1.81	1.86	1.93	1.98
2.0	0.88	0.90	0.93	0.97	0.99
3.0	0.59	0.60	0.62	0.64	0.66
4.0	0.44	0.45	0.46	0.48	0.50
5.0	0.35	0.36	0.37	0.38	0.40

**Table 7.19.** Levelized annual cost (cents/kWh, 1990/91 prices)

PLF (%)	Discount rates				
	3%	5%	7%	10%	12%
61	1.97	2.01	2.06	2.15	2.21
65	1.96	2.00	2.05	2.13	2.18
68	1.95	1.99	2.04	2.11	2.16
70	1.95	1.99	2.03	2.10	2.15
75	1.94	1.97	2.01	2.08	2.13

(i) The costs mentioned in EPRI (1988) of \$175/kW installed capacity and 18 mills/kWh O&M cost would be applicable to the Indian Situation.

(ii) 4900 hours of generation.

(iii) Coal consumption = 0.65 kg coal/kWh electricity generated.

- (iv) 90% removal efficiency of wet scrubbing process.
- (v) Uncontrolled emissions of sulphur dioxide were estimated at 19 times sulphur content of coal (T.T.Shen, 1980).
- (vi) 0.5% sulphur content in coal (average Indian coal).
- (vii) Life of an FGD assumed to be 30 years.

Sensitivity analysis on the sulphur content in coal revealed as expected, that the larger the content of sulphur in coal, the lower becomes the costs of removing it. This explains why it is not economical to install FGDs for low sulphur Indian coal, except perhaps for Assam coal and is an indication that the reduction of SO<sub>2</sub> emissions using FGDs is not worth the cost of installing such preventive equipment. In very stressed environments, however, such as that of Delhi and Singrauli, it could well be that the cumulative damage potential of even low emissions of SO<sub>2</sub> could be perceived as worth incurring the expenditure. All equipment costs are subject to an annual average real price inflation of 1.5%. This has been carried out for all equipment except FGDs since the calculations do not involve a time frame for installation. Hence even in terms of an avoidance cost, these figures indicate a lower bound.

#### Alternative strategy I

This strategy allows for efficiency improvements in the power sector in terms of coal washing and T&D loss reduction. These two measures contribute to reduced air pollution. Both these measures have been treated as energy supply technology costs (section 7.4) rather than as environmental control costs.

- 1 Particulate emission: Table 7.20 provides a summary of the minimum cost of environmental damage from TSP emissions from power plants by energy region for a 5% and 6% GDP growth rate at various discount rates. The cost per unit TSP removed ranges from 0.235 cents/kg at a 3% discount rate, to about 0.282 cents/kg at a 5% discount rate to about 0.478 cents/kg at a 12% discount rate. The TSP pollution cost per unit of electricity generated ranges between 0.036 cents/kwh at a 3% discount rate 0.043 cents/kwh at a 5% discount and 0.073 cents/kwh at a 12% discount rate.

**Table 7.20. Total environmental damage from TSPs from coal based thermal power plants for the period 1990-2010**  
( '000 \$) (1990/91)

Region	3%	5%	7%	10%	12%
<b>5% GDP growth rate</b>					
North	38.93	46.62	55.13	69.11	79.01
West	67.99	81.43	96.30	120.71	138.00
South	60.0	71.86	84.98	106.52	121.78
East	58.60	70.18	83.00	104.04	118.95
North East	n.a.	n.a.	n.a.	n.a.	n.a.
All India	225.53	270.09	319.42	400.37	457.74
<b>6% GDP growth rate</b>					
North	58.09	69.57	82.27	103.12	117.9
West	94.54	113.21	133.89	167.83	191.87
South	84.46	101.14	119.62	149.94	171.42
East	54.22	64.93	76.79	96.25	110.04
North East	n.a.	n.a.	n.a.	n.a.	n.a.
All India	291.3	348.86	412.57	517.14	591.23

The assumptions made to arrive at these costs are the same as those for the BAU strategy, except that power plants running on washed coal use 0.44 kg of coal per kWh generated and operate for 5330 hours per year.

- 7.5.4.2 Nitrogen oxide emissions: Table 7.21 provides a summary of the lower bound of the cost of environmental damage (as measured by its control cost) from NO<sub>x</sub> emissions from thermal power plants by energy region for a 5% & 6% GDP growth rate at various discount rates using SCR. The cost per unit NO<sub>x</sub> removed ranges from \$1.45/kg at a 3% discount rate to \$1.48/kg at a 5% discount rate and \$1.59/kg at 12% discount rate. The NO<sub>x</sub> cost per unit electricity generated ranges between 0.68 cents/kwh at a 3% discount rate and 0.75 cents/kwh at a 12% discount rate. The levelized annual costs of NO<sub>x</sub> control range from 0.583 cents/kwh at 3% discount to 0.595 cents/kwh at 5% and 0.644 cents/kwh at 12% discount rate respectively.

**Table 7.21.** Total environmental damage from NOx from coal based thermal power plants (1990-2010)

(\$ million) (1990/91 prices)

Region	3%	5%	7%	10%	12%
<b>A. 5% GDP Growth Rate</b>					
North	66.34	67.44	68.66	70.66	72.07
West	112.37	114.28	116.40	119.87	122.33
South	96.15	97.83	99.69	102.74	104.90
East	90.40	92.04	93.85	96.82	98.91
North East	n.a.	n.a.	n.a.	n.a.	n.a.
All India	365.29	371.61	378.61	390.09	398.23
<b>B. 6% GDP Growth Rate</b>					
North	82.64	84.27	86.07	89.03	91.12
West	131.26	133.91	136.83	141.64	145.04
South	114.18	116.54	119.14	123.42	126.44
East	72.79	74.3	76.0	78.71	80.65
North East	n.a.	n.a.	n.a.	n.a.	n.a.
All India	400.88	409.01	418.01	432.78	443.25

Once again the assumptions of the BAU strategy hold for this analysis.

4.3 Sulphur oxide emissions: Since FGDs are not currently a planned option, one does not know the time frame in which it will be installed. Further, coal washing (for ash) will reduce sulphur content of coal only marginally. Hence there is no change in the cost estimates of SOx emissions from the BAU strategy.

#### 5 Alternative strategy II

This is the strategy where renewable energy technologies will find wide application; the thermal capacity expansion remaining the same as under the 5% and 6% GDP growth rates of the BAU strategy. Hence, all cost estimates arrived for the BAU strategy will hold for this strategy as well.

#### 6 Combination strategy

This allows for efficiency improvements of Strategy I and RET capacity additions of Strategy II. The expansion of thermal power systems -- and hence environment related costs -- arrived at for Strategy I hold true for this strategy as well.

7.5.7 Value of forests lost due to hydropower and coal projects  
As seen earlier in the study, hydropower and coal mining projects have had a considerable impact on forest area, either due to submergence (for hydroprojects) or deforestation (for coal and lignite mining activity). As damage is clearly established, damages are valued at economic prices. To assess the value of forest area lost due to hydro and coal projects, the following are identified for each energy region: (i) the extent of forest land affected, and (ii) the type of forest involved. The value of forest lost by type (per hectare) is then assessed in terms of its goods and services. The value of the forest land lost is then assumed to be the present worth of goods and services foregone by society on account of energy projects\* at the various discount rates referred to earlier.

The value of a unit area of forest is estimated for each forest type based on both economic goods and environmental services provided by a forest. The value of environmental services (such as production of oxygen, conversion to animal protein, soil conservation and maintenance of soil fertility, recycling of water and humidity control, sheltering of birds, and control of air pollution etc.) are taken from Das (1980) in the absence of any other information. Surrogate market techniques are used to value such benefits from a medium sized tree which has a biomass yield of 50 tons over a period of 50 years\*\*. On the basis of these estimates, the value of environmental services provided by one tonne of biomass is about \$59 at current prices. An average organic productivity level per hectare is used for four types of forests - tropical, subtropical, temperate and alpine, as a basis for the calculations shown in Appendix 7.4. The economic goods considered are timber and industrial wood, fuelwood, minor forest produce, grazing and recreation. Stump values are estimated for timber, industrial wood and

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\* It could well be that some hydro and coal project do include timber costs in their economic appraisal. It is not clear, however, which projects do so. In the absence of information we assume here that forest loss in terms of timber are not included in the appraisal. Environmental services of forests are however, not included in any such appraisals.

\*\* Time and resources did not permit us to a separate valuation of environmental services provided by forests.

fuelwood. The present worth of a forest is then estimated as the sum of the annual streams of economic goods and environmental services. This is summarized at various discount rates in Tables 7.22 to 7.24.

Economic losses of forest submergence are given in Table 7.22, and for deforestation from coal and lignite mining projects in Tables 7.23 and 7.24. Since, coal production remains the same across strategies the environmental impacts also remain the same. Table 7.25 provides an average estimate of the forest lost per tonne of coal for the various energy regions.

**Table 7.22.** Value of forest area lost due to hydroprojects  
(1990-91 prices) (million \$)

Region	Forest affected (ha)	Capacity (MW)	12%	10%	7%	5%	3%
North	9452.66	9124.50	67.14	80.16	111.57	147.59	208.01
South	3114.50	1500.00	44.62	53.27	74.15	98.09	138.24
West	1711.00	1360.00	5.39	18.55	25.82	34.15	48.13
East	69899.00	4168.00	1001.41	1195.6	1664.2	2201.43	3102.59
Central	18.50	1260.00	0.07	0.09	0.12	0.16	0.22
Total	84195.66	17412.50	1118.63	1347.67	1875.86	2481.42	3497.19

Note: These figures reflect the value of forest area lost due to approximately 35% of the installed capacity in the period 1990-2010. Therefore, it is only a partial evaluation of the total forest loss due to power projects.

**Table 7.23.** Value of forest area affected by coal mining projects  
(1990-2010) (million \$)

Region	Forest area (ha)	Forest type	Coal production (10 <sup>6</sup> tons)	Discount Rates				
				12%	10%	7%	5%	3%
West	34661	TDD	245.27	186.34	222.48	309.67	409.64	577.35
East	10999	TDD+TMD	48.01	108.36	129.37	180.07	238.20	335.72
South	12885	TMD	17.36	184.60	220.40	306.78	405.82	571.96
North-East	225	TWE	2.3	2.66	3.18	4.43	5.86	8.25
All India (Total)	58770		312.94	481.97	575.42	800.95	1059.52	1493.27

TDD : Tropical Dry Deciduous

TMD : Tropical Moist Deciduous

TWE : Tropical Wet Evergreen

**Table 7.24.** Value of forest area affected by lignite mining projects

(1990-2010) (million \$, 1990 prices)

Region	Forest area (ha)	Forest Type	Lignite Prod. (million t)	Discount Rates				
				12%	10%	7%	5%	3%
West	179	TDD+TMD	0.78	1.76	2.1	2.92	3.86	5.45
South	13279	TMD	17.89	190.25	227.15	316.17	418.24	589.46
All India	13458		18.67	192.01	229.25	319.09	422.1	594.91

Note: In the Northern Region, lignite is mined in the State of Rajasthan which does not have any area under forests. Hence, this exercise was not undertaken.

**Table 7.25.** Average value of forest loss per tonne of coal produced

	Discount rates				
	12%	10%	7%	5%	3%
\$/tonne of coal produced	1.54	1.84	2.56	3.39	4.77

#### 7.5.8 Value of land affected by developing of overburden from coal mining projects

An attempt was made to value the land affected by the overburden generated by coal and lignite mining projects. The additional production from open cast mining is taken as the basis for this calculation, with a stripping ratio of 3 m<sup>3</sup>/t, to obtain the total overburden created by coal mining\*. Of the total life time (35 years) overburden, 10% is assumed to be external overburden. This overburden would be dumped on land outside the quarry area which has to be levelled, contoured and renourished after a period of time. Total area required for external dumps from opencast coal projects is estimated and land reclamation costs per hectare are calculated using normative costs per tonne of coal as estimated by the Planning Commission (1988). Land reclamation costs per hectare calculated are \$ 9190. The same norm is used to estimate the value of land affected by the overburden by lignite projects. Tables 7.26 and 7.27 summarize the area and the costs of reclamation involved in coal and lignite projects being developed in the period 1990-2010.

**Table 7.26.** Value of land affected by external overburden from coal mining projects

(1990/91 prices)		
Region	External dump area reqd.(ha)	Reclamation cost (million \$)
East	4865	44.7
West	1746	16.0
South	489	4.5
North-East	69	0.6
All India (Totals)	7169	65.9

**Table 7.27.** Value of land affected by external overburden from lignite projects

(1990-91 prices)		
Region	External dump area reqd.(ha)	Reclamation cost (million \$)
West	23.37	0.2
South	536.67	4.9
North	65.4	0.6
All India	625.42	5.7

Note : All lignite production is from open cast projects.

It is assumed for this exercise that any overburden from existing mining projects is being used for refilling the open pits. Dumping considered here is for new projects only.

Thus, at a minimum, the value of land affected by the dumping of overburden from opencast coal and lignite mining over the period 1990/91 to 2009/10 is estimated at \$65.9 million and \$ 5.7 million, respectively using reclamation costs as a minimum value placed on getting land back to its original condition.

### **Total economic costs**

Table 7.28 gives the total economic costs associated with various development strategies. These include direct economic costs related to demand and supply side investments and operations, as well as environmental costs.



**Table 7.28.** Total economic costs incurred in various development strategies (\$ million, 1990-91 prices)

	BAU	ALT-I	ALT-II	COM
<b>5% GDP growth rate</b>				
Technology	171776	137645	171473	138110
Energy shortage	4847	2259	4641	1467
Environmental	4474	3691	4474	3691
<b>TOTAL</b>	<b>181097</b>	<b>143595</b>	<b>180588</b>	<b>143268</b>
<b>6% GDP growth rate</b>				
Technology	195796	158504	195486	158008
Energy shortage	8480	1320	8297	1309
Environmental	5004	4284	5004	4284
<b>TOTAL</b>	<b>209280</b>	<b>164108</b>	<b>208787</b>	<b>163601</b>

**Note:** Environmental costs constitute approximately 2.5% of the total costs for each of the strategies. However, this figure is only a partial evaluation, e.g., water quality impacts across the energy system, air and soil degradation for the enduse stage, etc., have not been costed.

It may be noted from Table 7.28 that in both the low and high GDP growth cases, the combination strategy entails the lowest cost, followed closely by alternative strategy I, and the BAU strategy entails the maximum costs.

#### .7 Monetary estimates of environmental impacts of energy production and use for Singrauli and Delhi

Certain regions/cities are expected to come under severe environmental stress in future, if activities expand to the year 2010 as planned. In chapter IV, location specific environmental impacts for Singrauli and Delhi are given. In this section, we try to place a monetary value on these impacts following the same approach as that used for the rest of the country.

## 1 Singrauli region

- 1.1 **BAU strategy:** The impacts valued in the Singrauli region in the year 2010 assuming a power generating capacity of 10,510 MW are from total suspended particulates, oxides of nitrogen and sulphur dioxide, forest lost due to coal mining projects and land affected by external overburden dumps. The estimates are summarized in Table 7.29 through 7.32 below.

Total land estimated to be affected by external overburden dumps from coal mining projects is 732 ha. Total reclamation expenditure estimated is \$6.72 million.

**Table 7.29.** Relating to TSP emissions from power plants  
(1990-91 prices)

	3%	5%	7%	10%	12%
1. Levelized annual costs (cents/kWh)	0.037	0.045	0.053	0.066	0.075
2. Cost/unit TSP removed (cents/kg)	0.180	0.210	0.250	0.310	0.370
3. Total environmental damage ('000 \$) (1990-2010)	45	54	64	80	92

**Table 7.30.** Relating to SOx emissions from power plants  
(1990-91 prices)

	3%	5%	7%	10%	12%
1. Levelized annual costs (cents/kWh)	2.60	2.70	2.70	2.80	2.90
2. Cost/unit SOx removed (\$/kg)	4.57	4.67	4.78	4.96	5.08
3. Total environmental damage (million \$) (2010)	170	180	180	190	190

**Table 7.31. Relating to NOx emissions from power plants**  
(1990-91 prices)

	3%	5%	7%	10%	12%
1. Levelized annual costs (units/kWh)	0.76	0.77	0.78	0.80	0.82
2. Cost/unit NOx removed (cents/kg)	1.49	1.52	1.54	1.58	1.61
3. Total Environmental damage (million \$) (2010)	81	82	84	86	88

**Table 7.32. Value of forest area affected by coal mining projects**

Forest area acquired (ha)	Forest type	Value at various discount rates				
		3%	5%	7%	10%	12%
		(million \$, 1990/91 pr)				
95,000	TDD+TMD	289.96	205.74	155.53	111.74	93.59

7.7.1.2 Alternative strategy I: In this strategy the capacity is assumed to remain the same as in the BAU. However, all new capacity added after the year 1990 will operate on washed coal. Environmental costs related to coal mining are the same as in the BAU strategy (production remaining the same). Table 7.33 gives emissions and cost details for TSP.

**Table 7.33. Relating to TSP emissions from power plants**  
(1990-91 prices)

	3%	5%	7%	10%	12%
1. Levelized annual costs (cents/kWh)	0.036	0.043	0.05	0.063	0.072
2. Costs/unit TSP removed (cents/kg)	0.210	0.250	0.300	0.370	0.420
3. Total environmental damage ('000 \$) (2010)	45	54	64	80	91

SO<sub>x</sub> emissions were difficult to evaluate since washing for ash would also remove the inorganic sulphur in the coal, and this figure was not available. However, since total emissions are expected to be lower, the total environmental damage will be lower than the BAU. Therefore, the figures in Table 7.3 for the BAU would serve as a upper bound for environmental damage.

NO<sub>x</sub> emissions do reduce by 9.5% from the BAU. However, due to lack of specific detail on technical and equipment cost data, the numbers for total environmental damage arrived at in Table 7.31 can be used as a upper bound estimates.

7.7.1.3 Alternative strategy II: Both the costs and the total environmental damage from from TSP, NO<sub>x</sub> and SO<sub>x</sub> emissions from thermal power plants remains the same as in the BAU strategy.

7.7.1.4 Combination strategy: Costs and total environmental damage from TSP, NO<sub>x</sub> and SO<sub>x</sub> emissions from thermal power stations remain as in alternative strategy I.

#### 7.7.2 Delhi

As mentioned in Chapter 4, the three major polluting sectors in Delhi are power, transport and industry. While, it has been assumed that industrial growth in Delhi would be frozen more or less at present levels, the growing sectors of this region are essentially the transportation sector and power generation. An additional installed capacity of 210 MW is proposed in this region at an annualised cost (net of fuel) of \$311 million.

#### BAU (Power)

The impacts valued for the city of Delhi from emissions from power plants planned for the city to the year 2010. Tables 7.34 through 7.36 summarize the monetary values for TSP, NO<sub>x</sub> and SO<sub>x</sub> using the same approach and consumption as before.

**Table 7.34. Relating to TSP emissions from power plants  
(1990-91 prices)**

	3%	5%	7%	10%	12%
1. Levelized annual costs (cents/kWh)	0.033	0.04	0.047	0.059	0.067
2. Cost/unit TSP removed (cents/kg)	0.16	0.19	0.23	0.28	0.32
3. Total environmental damage (thousand\$) (1990-2010)	3.70	4.43	5.23	6.56	7.5

**Table 7.35. Relating to SO<sub>x</sub> emissions from power plants  
(1990-91 prices)**

	3%	5%	7%	10%	12%
1. Levelized annual costs (cents/kWh)	1.98	2.03	2.09	2.18	2.24
2. Cost/unit SO <sub>x</sub> removed (\$/kg)	3.57	3.66	3.76	3.92	4.04
3. Total environmental damage (million \$) (1990-2010)	12.3	12.6	13.0	13.5	13.9

**Table 7.36. Relating to NO<sub>x</sub> emissions from power plants  
(1990-91 prices)**

	3%	5%	7%	10%	12%
1. Levelized annual costs (cents/kWh)	0.57	0.58	0.59	0.61	0.62
2. Cost/unit NO <sub>x</sub> removed (\$/kg)	1.14	1.16	1.18	1.22	1.25
3. Total environmental damage (million \$, 1990-2010)	5.6	5.7	5.8	6.0	6.1

**Alternative strategy I (Power)**

For this case we consider the capacity expansion of 210 MW to occur using wash coal as input. The details are found in Tables 7.39 through 7.41.

**Table 7.37.** Relating to TSP emission from power plants  
(1990-91 prices)

	3%	5%	7%	10%	12%
1. Levelised annual costs(cents/kWh)	0.038	0.046	0.054	0.068	0.077
2. Cost/unit TSP removed(cents/kg)	0.330	0.390	0.470	0.580	0.670
3. Total environmental damage ('000 \$) (1990-2010)	0.890	1.060	1.250	1.570	1.800

**Table 7.38.** Relating to SOx emission from power plants  
(1990-91 prices)

	3%	5%	7%	10%	12%
1. Levelised annual costs(cents/kWh)	2.60	2.66	2.73	2.84	2.91
2. Cost/unit SOx removed (\$/kg)	6.90	7.00	7.30	7.50	7.70
3. Total environmental damage (million \$) (1990-2010)	3.30	3.40	3.50	3.60	3.70

**Table 7.39.** Relating to NOx emissions from power plants  
(1990-91 prices)

	3%	5%	7%	10%	12%
1. Levelised annual costs(cents/kWh)	0.75	0.76	0.77	0.79	0.81
2. Cost/unit NOx removed (\$/kg)	2.20	2.30	2.30	2.40	2.40
3. Total environmental damage (million \$)	1.50	1.60	1.60	1.60	1.70

Alternative strategy II (Power)

All costs and estimates of environmental damage are the same as under the BAU scenario.

Combination strategy (Power)

All costs and estimates of environmental damage are the same as under alternative strategy II.

Transport sector (Delhi)

The rapid increase in vehicular population in Delhi, the heavy levels of congestion and increase in pollution have highlighted the need to have a mass rapid transport system for the city of Delhi. The economic viability of this option has already been established earlier in this chapter. If one was to assume that this mass rapid transport system would be fully functioning by 2009-10, then the annual reduction in emissions resulting from the displacement of a portion of the vehicular population is given in Table 7.40.

**Table 7.40.** Emission reduction -- Metro option (Delhi, 2010)  
(tonnes per annum)

	CO	HC	NOx	SO <sub>2</sub>	TSP
Total	228117	119595	8157	905	4011

## Appendix 7.1

### Regional Break-up of Economic costs of Energy Supplies in 2009/10 (5% GDP growth case)

	BAU Strategy	Strategy ' I	Strategy II	Combination Strategy
<u>A. Regional distribution of costs excluding natural gas pipelines, fuel imports and power shortages (\$ million, 1990/91 prices)</u>				
NR	34029	23140	34078	23210
WR	44560	43948	44616	43767
SR	30097	28599	30189	28921
ER	26604	23270	26680	23334
NER	9942	9538	9956	9549
AI	145234	128495	145520	128781
<u>All India costs including</u>				
Nat. gas pipelines	171776	137645	171473	138110
Power shortages	176623	139904	176114	139577



## Appendix 7.2

### Regional Break-up of Economic costs of Energy Supplies in 2009/10 (6% GDP growth case)

	BAU Strategy	Strategy I	Strategy II	Combination Strategy
<hr/>				
A. <u>Regional distribution of costs excluding natural gas pipelines, fuel imports and power shortages (\$ million, 1990/91 prices)</u>				
NR	37433	26814	37483	26873
WR	48725	48113	48782	47685
SR	33291	32464	33382	32835
ER	29324	22374	29399	22448
NER	10751	10106	10751	10117
AI	159525	139871	159796	139958
 <u>All India costs including</u>				
Natural gas pipelines	195796	158504	195486	158008
Power shortages	204276	159824	203783	159317
<hr/>				

### Appendix 7.3

#### Economic Costs of Electricity Supplies in 2009/10 (1990/91 US cents/kWh sales) \*

	BAU Strategy	Strategy I	Strategy II	Combination Strategy
<b>A. <u>Low GDP Growth Case</u></b>				
NR	15.91	13.45	15.80	13.35
WR	12.65	11.79	12.45	11.61
SR	14.16	13.34	13.76	12.96
ER	15.49	14.85	15.36	14.70
NER	15.70	14.58	15.53	15.34
AI	14.57	13.18	14.37	13.03
<b>B. <u>High GDP Growth Case</u></b>				
NR	16.24	13.47	16.15	13.38
WR	13.11	12.31	12.92	12.02
SR	14.73	13.53	14.35	13.22
ER	16.08	14.35	15.95	14.20
NER	15.30	15.41	15.12	15.23
AI	14.99	13.31	14.80	13.13

\* In comparison, the cost of electricity generated through windfarms and small hydropower installations is US cents 20 and 14 per kWh of sales respectively.

Appendix 7.4 Value of a Forest per hectare (US \$, 1996/97 prices)

Forest	Typical Species	Forest	Typical Species	Protection (inv. services)	Timber and local use (timber/ha)	MP (ha)	Grazing (ha)	Recreation (ha)	Present worth per hectare (60 years)	Discount rates
1	2	3	4	5	6	7	8	9	10	11
Tropical wet Evergreen	Dipterocarps/ Nothof	Tropical wet Evergreen	Dipterocarps/ Nothof	531.5 (171.75)	643/ha (611.11/ha)	3.00 (0.31)	0.06 (0.06)	0.06 (0.06)	36670.43	1000.01
Tropical Semi Evergreen	Richtia Nepes Ternstroemia	Tropical Semi Evergreen	Richtia Nepes Ternstroemia	531.5 (171.75)	643/ha (611.11/ha)	3.00 (0.31)	0.06 (0.06)	0.06 (0.06)	36670.43	1000.01
Tropical Moist Deciduous	Tual/Sal Bambusa	Tropical Moist Deciduous	Tual/Sal Bambusa	531.5 (171.75)	643/ha (611.11/ha)	3.00 (0.31)	0.06 (0.06)	0.06 (0.06)	36670.43	1000.01
Upland and Swamp	Dipterocarps/ Santal Artocarpus	Upland and Swamp	Dipterocarps/ Santal Artocarpus	531.5 (171.75)	643/ha (611.11/ha)	3.00 (0.31)	0.06 (0.06)	0.06 (0.06)	36670.43	1000.01
Tropical Dry Deciduous	Acacia/ Acacia/ Terminalia	Tropical Dry Deciduous	Acacia/ Acacia/ Terminalia	531.5 (171.75)	643/ha (611.11/ha)	3.00 (0.31)	0.06 (0.06)	0.06 (0.06)	36670.43	1000.01
Tropical Thern	Albizia/ Albizia/ Albizia	Tropical Thern	Albizia/ Albizia/ Albizia	531.5 (171.75)	643/ha (611.11/ha)	3.00 (0.31)	0.06 (0.06)	0.06 (0.06)	36670.43	1000.01
Tropical Dry Evergreen	Albizia/ Albizia/ Albizia	Tropical Dry Evergreen	Albizia/ Albizia/ Albizia	531.5 (171.75)	643/ha (611.11/ha)	3.00 (0.31)	0.06 (0.06)	0.06 (0.06)	36670.43	1000.01
Subtropical Broad leaved Hill	Albizia/ Albizia/ Albizia	Subtropical Broad leaved Hill	Albizia/ Albizia/ Albizia	531.5 (171.75)	643/ha (611.11/ha)	3.00 (0.31)	0.06 (0.06)	0.06 (0.06)	36670.43	1000.01
Subtropical Pine	Albizia/ Albizia/ Albizia	Subtropical Pine	Albizia/ Albizia/ Albizia	531.5 (171.75)	643/ha (611.11/ha)	3.00 (0.31)	0.06 (0.06)	0.06 (0.06)	36670.43	1000.01
Subtropical Dry Evergreen	Albizia/ Albizia/ Albizia	Subtropical Dry Evergreen	Albizia/ Albizia/ Albizia	531.5 (171.75)	643/ha (611.11/ha)	3.00 (0.31)	0.06 (0.06)	0.06 (0.06)	36670.43	1000.01
Montane Wet Temperate	Albizia/ Albizia/ Albizia	Montane Wet Temperate	Albizia/ Albizia/ Albizia	531.5 (171.75)	643/ha (611.11/ha)	3.00 (0.31)	0.06 (0.06)	0.06 (0.06)	36670.43	1000.01
Montane Moist Temperate	Albizia/ Albizia/ Albizia	Montane Moist Temperate	Albizia/ Albizia/ Albizia	531.5 (171.75)	643/ha (611.11/ha)	3.00 (0.31)	0.06 (0.06)	0.06 (0.06)	36670.43	1000.01
Subalpine Moist Alpine Scrub Dry Alpine Scrub	Albizia/ Albizia/ Albizia	Subalpine Moist Alpine Scrub Dry Alpine Scrub	Albizia/ Albizia/ Albizia	531.5 (171.75)	643/ha (611.11/ha)	3.00 (0.31)	0.06 (0.06)	0.06 (0.06)	36670.43	1000.01

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Overall assessment of the strategies

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**Multi-attribute assessment**

Of the entire set of impacts described in Chapter 4, impacts that differ amongst strategies and have not been costed are the transport and the industrial sectors. Therefore, the multi-attribute assessment need only be conducted for these sectors. Since only air emissions have been quantified for these sectors, the assessment is limited to 'airsheds' for each of the regions.

The impacts are assessed by considering the emissions of the five major pollutants (TSP, SO<sub>2</sub>, NO<sub>x</sub>, CO and HC) in the three zones (Chapter 4). The first step is the amalgamation of the zones in the regions to arrive at 'damage equivalent' emissions for each pollutant by assigning weights of 0.5, 0.4 and 0.1 for zones 1, 2 and 3 respectively, based on their relative damage potential. The next step is the aggregation of the pollutants to arrive at the 'damage equivalent' emissions for air as a whole. This is done by assigning weights of 0.18, 0.45, 0.36, 0.005, 0.005 for TSP, SO<sub>2</sub>, NO<sub>x</sub>, CO and HC respectively, again based on their relative damage potential. In the absence of a critical level, the 'damage equivalent' emissions for each of the strategies in the year 2010 have been used as a basis for comparison with the BAU. Table 8.1 gives the 'damage equivalent' emissions in the year 2010 for each of the strategies.

**Table 8.1.** 'Damage equivalent' emissions in the year 2010 across strategies ('000 tonnes)

	North	West	South	East	N-East	Total
5 % GDP growth rate						
BAU	2799.36	5729.21	4705.42	4872.33	108.74	18215.06
Strategy I	1860.45	3116.76	1812.99	1639.82	20.05	8450.07
Strategy II	2794.44	5726.61	4704.73	4871.49	108.39	18205.66
Combination strategy	1855.53	3114.16	1812.30	1638.98	19.70	8440.67
6 % GDP growth rate						
BAU	3880.85	7958.95	6356.62	7467.92	151.01	25815.35
Strategy I	2173.53	3503.78	1890.03	1891.75	27.31	9486.40
Strategy II	3875.92	7956.35	6355.93	7467.06	150.66	25805.92
Combination strategy	2168.60	3501.18	1889.34	1890.89	26.96	9476.97

As can be seen, both strategy I and strategy II have lower values than the BAU, with the combination strategy having the lowest 'damage equivalent' emissions. This result is also intuitively obvious, since both the strategies individually result in lower emissions than the BAU (strategy I is conservation based, resulting in relatively lower emissions than BAU; strategy II is essentially renewable energy based along with a small penetration of CNG in the transport sector, resulting in relatively lower emissions than BAU) and therefore, the combination of both sets of measures, results in a further reduction in emissions.

## **8.2 Ranking of the strategies**

The economic analysis in Chapter 7 and the Multi-attribute assessment have clearly shown the combination strategy to be the best, in which both conservation measures and alternative energy sources are considered. A comparison of the results of the alternative strategies I and II with the BAU strategy also suggests the desirability of implementing such measures. However, as the alternative strategies I and II comprise mutually exclusive options, it is not possible to compare them directly. The purpose is only to investigate the desirability of developments in these directions.

## **8.3 Constraints and issues encountered in the application of the methodology**

The methodology for this study takes a leap forward from traditional energy planning models in that it attempts to include environmental aspects in developing an 'optimal' strategy. However, environmental impacts are only partly generic, the impact depends not only on the effluents emitted, but also on the ambient environmental conditions, number of people exposed etc., i.e. it is extremely site-specific. Therefore, environmental aspects for a strategy in a region can only be captured after site-specific environmental evaluations have been conducted. This is an extensive task and can only be accomplished on identified sites. This poses a major constraint on the use of this methodology, for it can only be used for planning in the short and perhaps the medium term, but not for strategic analysis. This issue needs to be addressed, and is an area for future research.

Constraints on demand projections.

For each energy consuming sector, information on its energy use patterns and determinants of its energy demand was only partially available -- a feature which impelled frequent resort to making educated and informed guesses.

This is particularly true for the residential and agricultural sectors. As far as households are concerned, available data are gathered from field surveys. Most field surveys are only one time exercises and do not shed any light on the evolution of energy use patterns in any rural or urban community in the past. In the urban households in particular, where appliance ownership patterns have changed considerably in the past decade (a trend which is likely to continue in the foreseeable future), there is little information, if any, on the utilization of these appliances. Needless to say, differences in energy consumption patterns across various income/expenditure category households is documented even less. Likewise, little is known on the changes in population over various income/expenditure categories.

In the agriculture sector, energy end-use data are again not compiled systematically, and the use of norms based on sample surveys may not always be desirable -- but is perhaps the only option.

As far as the transportation sector is concerned, available data are aggregated to the extent that it is usually not possible to derive any meaningful information on inter-state and inter-regional movements of goods.

It was not possible to use elasticities of demand to project energy demand because of (1) the system of administered pricing in India, (2) the constrained demand and the lack of flexibility to respond to changes in prices/income, (3) income data is highly uncertain, and (4) a large part of energy is consumed by the Government or the public sector which tends to be unresponsive to price signals.

Under such circumstances using demand elasticities to project demand would not be a realistic exercise.

Constraints on supply projections

The main constraints on the supply side emerged from the long time frame of the exercise, and the lack of information on energy supply plans beyond the year 2000. For example, for the power sector, schemes for coal TPS, nuclear, hydro and GT/CCP, are fairly well known only until the year 2000. For

the period beyond 2000, extrapolations were made keeping in view the shares of various types of capacity in different regions.

Another major problem relating to power system expansion projections stemmed from the fact that only peak power and energy demand forecasts were available. Owing to the fact that the various conventional generation options (hydro, coal, TPS, GT/CCP, nuclear) and RETs (windfarms and small hydro) are not exactly technically substitutable, the analysis of supply options would be better if a load duration curve (LDC) were available for the year 2009/10. In fact, even a three-step load duration curve will be significantly better than the peak power and energy demand forecasts used here. However, projecting LDCs entails intensive data requirements, including the sectoral LDCs at present and anticipated changes in them to 2010. Even if the present sectoral LDCs were available (through a representative sample field survey in each region), it would be difficult to project them as the existing power shortages (which are much higher than projected levels) distort them significantly. Moreover, an increase in electricity using equipment and appliances in the coming years will also influence the sectoral LDCs considerably.

Lack of detailed geological information on the various petroliferous basins resulted in the projections being based on average gas to oil ratios and expected discovery index, and indicative costs per metre of exploration and drilling. It is fully recognized that this is not the best way to project oil and gas supplies, especially since it does not capture the probabilistic nature of the discovery process at all. However, it was the only way to project supplies in the absence of more detailed basinal information.

In the case of coal supplies, reasonably firm plans were available until 1994/95. Beyond this, it was necessary to extrapolate based on an assumption that coal development efforts would be rationalized in line with the presently known reserves position.

The projections for biomass availability were even more difficult to undertake because wide variations existed in the estimates of biomass availability, particularly of firewood. In this case, the approach was to use average figures for yield/availability, collection efficiency, etc.

Similarly, because it was not possible to predict the quality of crudes that will be used in refineries, refinery yields of various fractions were based on normative data.

### .3 Prediction of changes in environmental quality

For reasons mentioned in section 8.3 coupled with a lack of data, permitted only a partial coverage of the environmental impacts. A major drawback is the absence of site-specific information. For example, forest land submerged by hydro projects was only available for 38% of the planned capacity up to the year 2000. It is also not possible to use averages since data available on forest submergence/MW capacity revealed a range of three orders of magnitude. Similarly, information on relevant water quality parameters for stretches of rivers where the siting of future thermal power plants has already been done was not available, thereby restricting the evaluation of water quality impacts. In fact a major constraint in predicting changes in environmental quality was the lack of baseline information available on the country from which energy-related changes could be measured. However, impacts are not always separable in causal factors, and as such it was difficult to categorically establish a cause-effect relationship between energy development and environmental impacts, for example, in the case of reduced soil fertility in the vicinity of coal mining projects.

### .4 Economic analysis

.4.1 Valuing environmental impacts: The constraints on predicting impacts did, but naturally, limit the valuation exercise. The choice of techniques that were used were determined largely by the availability of data, the nature of impacts to be valued, and the limitations of time. In general, direct and indirect techniques may be employed to value the environment. Direct techniques, such as experimental techniques, or those that use a surrogate market, are used essentially to value environmental gain from environmental improvement programmes. However, all these techniques are highly information intensive, and require the collection and analysis of a large amount of data. Indirect techniques do not measure direct revealed preferences for the environmental good in question but seek, instead, to calculate a 'dose response' on impact relationship between pollution and some effect, for example, impact of air pollution on crops, health of people, etc., and then use some measure of preference to value that impact. These are second-best approaches to valuation and involve methods such as preventive expenditures, replacement costs, damage costs avoided, etc. This study has, as seen in Chapter 7, used indirect techniques to value environmental impacts. However,



there were a number of difficulties faced even in doing this limited exercise, arising essentially out of a lack of location specific information. For example, lack of detailed forest cover (density) information available for the sites affected by coal and hydro projects resulted in this important element being ignored in the costing exercise.

As discussed earlier, a critical input in using indirect valuation techniques for environmental costing is the identification of dose-response relationships. This would typically require very detailed data on ambient air concentrations and pollutant loading, as necessary information. However, to assess the damage potential would require the use of dispersion models and would need to be carried out at a much more micro level than the regions defined for this study would permit. However, even if this were possible, to establish a link between mortality or poor health or reduced crop yield, and pollution, would require a large data bank of these and other socio-economic variables. No such level of detailed information is available in the country -- although an attempt was made to overcome this problem, albeit to a limited extent by 'zoning' the regions.

Most of the above constraints have resulted in cost estimates which are believed to be essentially lower bound values on environmental damage caused by energy activities (the singular exception may be the deployment of FGDs for SO<sub>2</sub> control). This will serve more to build an awareness of environmental considerations rather than to definitely place a value on energy-related environmental damage.

- 8.3.4.2 Other aspects of the economic analysis: The economic analysis of the three strategies was based on an evaluation of the direct economic costs associated with each of the strategies for each sector and region. Some of the cost estimates were developed in efficiency terms using standard conventions. However, it was not possible to derive economic prices in various cases and normative costs (based on some average or expected values) have been used. For example, in the case of power plants or coal mining capacity, \$/kW of installed capacity in the former case and \$/tonne in the latter case have been assumed without considering the implications of actual site conditions on investment requirements. Likewise, only normative O&M costs for energy production/conversion and environmental control equipment have been considered. For capital costs for environmental control equipment (namely, ESP, FGD, SCR) one had to rely on international costs information (per installed capacity) found relevant to the Indian case.

In the absence of detailed information, the study estimated fuel transportation costs for example, from coal mines to a TPS unit in a region by treating each region as a single destination point. It is acknowledged that this may not have led to good estimates of fuel transport costs.

}.4.3 Multi-attribute assessment: The system for scoring environmental impacts is developed, based on a critical level in the region for the parameters in question. When one is dealing with concentrations (air quality, etc.), the ambient standards provide this level and the scoring system can readily be developed. However, when one is dealing with emissions (or effluents), this level is extremely difficult to define over a region, and therefore, an absolute scale cannot be constructed. This is a major limitation, since moving from emissions (or effluents) to concentrations over a region is an extensive task (amongst other things, extremely data and time intensive) and cannot be undertaken for a study of this kind. This is an area that needs future research, for a multi-attribute assessment can be useful in terms of evaluating environmental qualities specific to a particular region.



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### Conclusions and Recommendations

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#### **Institutional feasibility of implementing most desirable plan**

While discussing the institutional feasibility of implementing the combination strategy, one needs to first identify those weaknesses which currently hinder the implementation of desirable plans. Some of the major weaknesses that underlie this area result from the separate treatment of energy and environmental issues in the planning process, even when they are in actual fact closely connected. These are as follows:

(1) Energy planning seldom takes into account environmental impacts, largely because there is a lack of appreciation and skills within the energy sector on the precise nature of environmental impacts both in physical and economic terms. Consequently, energy planners often treat the preparation of environmental impact assessment reports as a ritual and an unavoidable nuisance at best and do not look at the wider implications of energy decisions on the ecology, natural resource base and environmental quality of a specific region.

(2) The Ministry of Environment and Forests, which is the nodal point for environmental clearance of energy related projects is not fully involved in the assessment of energy demands and formulation of supply options. Nor is this Ministry conscious of the economic implications of shortages in energy supply or the gestation periods of energy projects. Consequently, sharp differences in priorities and perceptions exist between the energy related ministries on the one hand and the Ministry of Environment and Forests on the other. Even though environmental control organisations in several states of India are still not very effective and strong in their functioning, the same perceptions are evident in these organisations at the state level as well.

Consequently, the environmental protection and control authorities in the country generally do not look at economic trade-offs and options, but generally treat environmental quality as a matter of absolute purity.

(3) Environmental effects and implications are looked at purely on a project to project basis, and not in terms of broad strategies and directions and aggregate effects. This problem arises largely because the country does not have an integrated energy policy, and, essentially, plans are put together on the basis of specific fuel and energy types with little assessment of fuel switching possibilities and substitutes either on the demand side or on the supply side. Consequently, strategies which would strengthen environmental protection have not been looked at in aggregate terms, in the absence of which projects are considered individually purely on the basis of their respective technical, financial and institutional feasibility without regard to their aggregate effects on the environment. Current project impacts are assessed at the local level in most cases and rarely, if at all, at the global level, as for instance, in the case of emissions of carbon dioxide and other greenhouse gases (GHGs). Quite understandably GHG emissions are not a matter of major concern in India at present, and if at all this subject is to acquire importance in the future, it would be only on the basis of international agreements that might allow for financing of additional costs and technology transfers for addressing the problem of GHG emissions.

It is evident that in order to implement the energy conservation and renewable energy options (combination strategy), priority would have to be provided to the following programmes and projects.

#### 9.1.1 Energy conservation

Energy conservation efforts have thus far had to contend with irrational pricing of energy as exemplified by the heavy subsidies provided to irrigation pumping using electricity in the agricultural sector, as well as a lack of private sector and public participation in energy conservation programmes. The success of energy conservation in the future would depend on appropriate pricing of energy as well as public participation. For this purpose the setting up of a nodal organisation for energy conservation as recommended in the

mid '80s by the Advisory Board on Energy would be an essential first step. Such an organisation would necessarily have to be outside the Government but supported by the Government, so that it has credibility and clout in official terms, but without the encumbrances of government procedures and processes. Such an organisation could then act as a focal point for catalysing industry, the public and the media in evolving national strategies and plans for energy conservation. It could also then lay down specific standards in consultation with the Bureau of Industrial Standards for a large range of energy using equipment and appliances.

Specific programmes for each of the sectors are as follows.

Transport: Environmentally desirable options in the transport sector that need to be pursued during the 1990s and the first decade of the 21st century are listed below. None of these would be easy to implement with existing organisational and institutional arrangements. Hence a brief discussion is presented on institutional changes that are essential to realise these options.

1. Highway construction and maintenance: The economic analysis from Chapter 7 clearly shows that improved highway construction and maintenance would have significant benefits in terms of energy efficiency, alongwith other benefits like reduced pollution, reduced maintenance costs, etc. Given that the current arrangement for undertaking this activity is essentially through departments of the central and state governments, not only do improvements appear unlikely, but the prospect of mobilising additional financing seems bleak. Typical government budgetary procedures not only have inbuilt delays and lags but are also rigid in terms of expenditures that could be incurred within a certain budgetary period. Hence, it is common to find materials for road construction lying by the highway for long periods of time without mobilisation of other inputs which would make construction or repair possible. Improvements in this sphere of activity can come about if market forces were to create incentives for appropriate design, construction and upkeep of road networks. The involvement of the private sector and the introduction of payment for services by road users would bring about a major improvement in the condition of roads in the country and would also be able to harness the private sector for mobilising finances with a greater degree of flexibility.

As a workable plan of action, the Government should, in

the first instance, throw open the highways on which the highest density of traffic is found today by involving the private sector on a contract basis. Regulatory mechanisms could be built in to ensure that monopoly profits are not obtained by those operating and maintaining these systems. On the basis of experience thus obtained, perhaps in the next phase three years later, a larger section of the road network in the country could similarly be handed over for private sector management and operation. On the basis of a phased plan of action the bulk of the road transport infrastructure in the country should be brought under the management of the private sector.

2. Investments in urban rapid transit and metro facilities:

Several cities in India have reached a point where urban congestion and pollution cannot be contained without major innovations such as establishing rapid metro transport systems. An interesting case in point is the city of Delhi, which among the metropolitan areas of the country has a rapid rate of population growth, and by virtue of its geography, a very high level of per capita mileage in terms of urban transport. RITES has carried out a series of studies establishing the feasibility of an urban mass transit system, the most recent of which was completed in 1989. However, the Government has not been able to implement this project for want of institutional infrastructure in the city's local government and adequate finances for the massive investment required. Yet the benefits to society from an appropriate metro system would be substantial. The scale of funding required, namely US \$ 1.4 billion can only be mobilised from external sources. A concept that needs to be explored is that of the build-operate-transfer (BOT) option. This option would not only ensure quick and efficient implementation of the project but also bring into existence management and operational expertise which is essential for maintaining the system, once established, at high levels of efficiency. The Government of India should seriously consider pursuing this possibility for the city of Delhi to start with and other cities subsequently, if the experience with Delhi is successful.

3. Shifting of transport from roadways to railways: The last 30 years have witnessed a decline in the share of rail transport vis-a-vis road transport in India. In order to reverse this trend, the service provided by the Indian

Railways would have to improve substantially, and major technological upgradation would have to be brought about in the infrastructure and operations of the railways. In order to identify strategies for achieving this, the railways would first have to prepare a detailed perspective plan, in which it would be essential to get expertise and inputs from outside the system. Perhaps this is a possible technical assistance project which the ADB might consider pursuing. In essence, improvements in the hardware and technology of rail transportation would have to cover track renewal and upgradation, modernisation of signaling facilities, and improved technologies for traction equipment and rolling stock. The Indian Railways, like several other nationalised railway systems in the world, have been going through a period of difficult financial constraints. At the same time the technology gap between the Indian Railways and other systems in the world has grown progressively, and efficiency levels have remained more or less stagnant. There are strong organisational and institutional factors behind this trend. In essence, despite the commercial nature of railway undertakings in India, their functioning remains bound by government rules and procedures, and financing decisions are taken on the basis of sanctions by Parliament. To convert railway operations into a dynamic activity, the entire structure of the Indian Railways would have to be granted greater autonomy. As a first step, it would be necessary to convert the zonal railways into separate public sector undertakings, with the Railway Board functioning as a holding company. This would allow much greater flexibility and speed of decision-making to attract funds from the market for specific railway projects and programmes. The perspective plan mentioned above would necessarily have to cover the strategies for raising finances and capital resources from outside the budgetary process of the Government. Also, tariff decisions would need to be taken out of the purview of government decision making and left in the hands of a regulatory commission that could ensure both efficiency and equity in such decisions. Additionally the handling and management of 'smalls' in freight movement should be privatised, so that a greater market orientation is introduced in this component of traffic. This would win over much of the freight moved from road to rail.

Industry: The industrial sector, consuming approximately 40% of the total commercial energy offers an enormous potential for energy conservation, with measures having pay



back periods of 3 to 5 years. Amongst other options, two prime areas for energy conservation are co-generation, steam generation, transmission and distribution systems and electrical motors. A study by USAID for co-generation covering two states, Maharashtra and Gujarat, identifies a potential of over 10,000 MW for large scale power generation alone (100 - 200 MW). This could replace a major portion of expansion needs envisaged by the state electricity boards. But for this to become a reality even to a small extent, PURPA-type legislation and adequate credit facilities for co-generation projects would be essential prerequisites.

However, performance of industry in energy conservation has not been very encouraging. Undoubtedly, the motivation for efficient use of energy comes from market forces and the priorities of financiers and financial institutions. There are two major reasons why energy conservation programmes in Indian industry have not achieved great success, and these are, (i) lack of information and specialised knowhow and (ii) difficulties in obtaining capital from the financial institutions for clearly focussed energy conservation programmes. Two innovations are essential in bringing about a higher level of energy efficiency in the industry sector, and these are:

- (1) The setting up of a nodal organisation for energy conservation outside the government, but with the support of the government and industry, which may, over a period of time, promote similar organisations at the state level or even on a sectoral basis.
- (2) Instituting a specific window in each of the major financial institutions to deal with energy conservation projects.

Given the attractive rates of return from energy conservation, it is somewhat surprising that financial institutions have not taken a more active role in promoting conservation activities in industry. This has been largely the result of a lack of technical knowledge and an ignorance of opportunities for productive investments dealing with energy conservation. The financial institutions would have to include this set of opportunities in their policies and priorities in the future. Based on the availability of finance, several consulting firms and technical groups are likely to come up to fill up the gap in terms of technical expertise. There would also then be a movement towards energy service companies who can provide a full package of inputs to bring about improvements in energy efficiency in

the industrial sector.

- .3 Domestic: Domestic sector energy uses present large opportunities for efficiency gains and environmental benefits because not only is this sector projected to grow very rapidly in the future, but the economic incentives for improvements exist in the form of a large population of energy using appliances, wherein a small improvement would have a large multiplier effect. One factor inhibiting the improvement of appliance efficiency in India is the quality of power supply which inevitably results in over-designing of motor units, compressors and other such devices. It would be necessary to tackle this problem through a set of carefully controlled demonstration projects, wherein installations for voltage stabilisation and frequency control are made on a somewhat centralised basis rather than by each individual consumer. The social benefits of such a project would be substantial.

The standardisation of appliances in India leaves much to be desired. Even within the constraints of poor quality power supply, standardisation can bring about significant energy gains if implemented in a determined manner. This would have to be done through a detailed study of major energy using appliances, starting, for instance, with domestic refrigerators the population of which is likely to grow to 45 million by the year 2010. Refrigerator efficiency enhancements include improvements in basic design of the cabinet itself, the insulation material used, the compressor and refrigeration system and several other features of a standard refrigerator. Once standards have been set and targets laid down, improvements would have to come through a coordinated approach involving all the industries that are responsible for the manufacture of these components. While the initiative for these may be taken by the government, the actual implementation of such a programme would have to be carried out by industries themselves as part of a coordinated programme and in response to incentives, punitive measures or disincentives that the government may build into its strategy.

- ..4 Agriculture: What applies to the case of domestic refrigerators and other appliances also applies to agricultural pumpsets. Government policy in the past has favoured pumpsets being manufactured in the small scale sector, as a result of which compromises in design and quality of manufacture were the rule rather than the exception. It would now be necessary to lay down efficiency

standards for different designs of pumpsets and ensure their compliances in manufacture with a set of incentives and disincentives. Also, since a large number of pumpsets are purchased through financing from the nationalised banks and other development agencies, these banks could be made partners in the enforcement of standards, by eliminating the financing of sub-standard devices.

#### 9.1.2 Renewable energy technologies

9.1.2.1 Enhanced development and utilisation of renewable energy technologies: As seen from the analysis, wind power upto a certain percentage of the peak generating capacity can be viable and accepted by the system. It appears that in spite of all the constraints (discussed in Chapter 5) wind farm capacity additions of about 3000 MW is realisable by the year 2010. A certain percentage of capacity is expected to be installed by private industries which will wheel the energy generated to their plants. Measures here could include incentives in the form of tax benefits, etc. However, the major additions are expected to be either installed by the utility itself or by the private parties and intended for sale to the utility. Since the purchasing organisations, namely the state electricity boards are essentially monopsonies, legislation of the PURPA type would be essential not only to ensure adequate resources being allocated to this activity, but also to see that optimal choices are exercised in the location of wind power facilities on the basis of economic merit.

Small hydel capacity is also seen to be a viable option and a capacity of approximately 1500 MW is a realisable target till the year 2010. This capacity will be partly distributed amongst the grid connected and non-grid connected areas. The canal drop schemes which constitute a significant portion of the capacity and which have a relatively lower cost of generation are mostly distributed in grid connected areas. Although, the marginal costs of generation will be relatively higher for small hydel units other than canal drops in remote areas, it should be noted that the avoided cost of generation at such locations will also be higher.

Other economically viable technologies include biogas plants and solar cookers. Solar cookers dissemination programmes have been in existence for over a decade. In the rural areas they have not made much impact due to the inherent limitations of the technology mentioned above and

its cost. However, solar cookers have good potential in semi-urban and peri-urban areas where accessibility to fossil fuels is relatively less and where fuelwood is commercialised.

The optimal utilisation of renewable sources of energy would be dependent entirely on the development of a market with suitable response on both the demand and supply sides. While generally consumers would make rational decisions based on price and quality of renewable energy devices available in the market, on the supply side several existing distortions and restrictions would need to be removed urgently. The development of a renewable energy industry in India has been constrained by an over-centralised approach, which not only requires the approval of designs of devices for manufacture, but also permissions of various kinds to actually set up manufacturing. The system of subsidies further distorts the profile of the industry, whereby only a few manufacturers are able to reap the benefits of subsidies without strong incentives for competitive performance. Thus, not only is there inadequate improvement in designs and quality of manufactured products but also in after sales service and customer orientation. A complete delicensing and decontrol of the sector would be essential to bring about a large enough response in the evolution of a healthy market for renewable energy devices.

- 2 Reorientation of renewable energy R&D: The approach to research and development in renewable energy technologies requires major reorientation to bridge the gap between lab and land. Most of our work on renewables in the past has been concerned with theoretical research with little attempt to develop marketable products or devices. A correction of this trend requires not only an appropriate choice of institutions and organisations in which R&D should be promoted, but also a set of incentives and disincentives for product development and the involvement of industry in such efforts to ensure the rapid spread of appropriate technologies using renewables.

### **Measures on the overall energy system**

#### **Natural Gas**

The flaring of natural gas in India is a criminal waste which would not be allowed in any other country of the world. The reason for this continuing waste is the cumbersome decision

making structure and "turf" battles between different ministries and departments of the Government of India. The problem could be circumvented by setting up an empowered committee at a high level that could take decisions on complex questions of natural gas utilisation for a variety of applications, but this would be a cumbersome method which is likely to be subjected to pressures of various kinds and, therefore, optimal decisions are unlikely to emerge. A far more effective approach would be to regulate gas prices at the wellhead and allow markets to function through private sector participation in all the downstream activities related to natural gas supply and utilisation.

Given the fact that natural gas production is likely to be completely absorbed through consumption in the business-as-usual scenario, it would be useful to explore options for import of natural gas over and above the level allowed for in this scenario, if necessary by pipeline from countries such as Bangladesh and Iran. At this stage India could carry out feasibility studies of existing import options. These studies could perhaps be financed by the ADB along with the provision of suitable technical assistance. Since international negotiations and agreements as well as mobilisation of investments in infrastructure are long gestation activities, it is not anticipated that imports of natural gas will materialise to any great extent in the near future, but this is entirely possible within the time horizon upto the year 2010. As such, these options need to be explored and assessed seriously in view of their environmental and economic benefits.

#### 9.2.2 Oil

From the analysis, India's oil imports are increasing every year, and, even for the conservation strategy would need a level of 54 MT per annum in the year 2010. Therefore, It is essential to have a new hydrocarbons policy implemented under a new and different regime of relaxed controls and regulations in order to step-up indigenous production. The components of a new hydrocarbons policy would be,

1. An immediate increase in production without sacrificing the ultimate recovery of reserves already established.
2. Restructuring the hydrocarbons industry for achieving cost effectiveness in exploration, production and refining.

Immediate measures to be taken for increase in overall production of hydrocarbons would require an improvement in the reserves to production (R/P) ratio. In essence, thi

ratio which in various exercises carried out for the Eighth Five Year Plan is targetted at 16:1 in the terminal year of the Eighth Plan should be improved gradually to a level of 7:1. As it is, the R/P ratio in India is much higher than several other countries of the world. It should be possible even with existing reserves to increase production by around 10 million tonnes annually within the next 5 years. This would, however require a far more liberalised regime for investments and decision making and early mobilisation of resources to bring about such an outcome. Similarly, natural gas production can be increased to about 70 million cubic metres per day at the end of 5 years.

The achieving of higher productivity and efficiency in the hydrocarbons industry is dependent on major and far reaching organisational/institutional changes. The hydrocarbons industry must gradually move towards privatisation and reduced involvement of government in day-to-day decision making. For instance, under government rules, the finalisation of tenders can take up to two years, which no oil company in the world can afford.

The system of specific rounds for inviting foreign and private oil companies for exploration is outdated and cumbersome. Government must immediately announce a framework of policies for attracting foreign companies into oil exploration, and allow bids to be made regularly for specific areas which must be thrown open to the private sector and the international oil companies. Countries such as Malaysia and Indonesia which followed the rounds system earlier have given up this practice long ago.

Several small and marginal fields must be handed over to the private sector immediately for production from these locations on a contract basis. A number of private sector and joint sector companies may be allowed to enter the hydrocarbons sector by opening up exploration and production and also by converting ONGC into a public limited company with 10-15% equity holding by the public.

The state of technology in the hydrocarbons industry in India has lagged behind developments in other countries. A far more open approach has to be pursued for tying up of Indian oil companies with foreign companies for ensuring early improvements in hydrocarbons technology in the country.

- 1 Opening up refining to the private sector: Due to an increase in consumption of middle distillates our refinery configuration has become unbalanced, with the result that we have to import refined products at high cost. For reasons

cited in section 9.2.2 above, private sector participation including foreign oil companies is essential.

#### 9.2.3 Coal

The setting up of coal washeries is an option that needs to be vigorously pursued. This option is economically viable, having multiple benefits in the form of better plant performance, reduction in ash-handling equipment, improvement in ESP removal efficiencies, and a reduction in the transportation costs. The heat value of washery rejects can readily be exploited by combustion in an AFBC boiler located at the washery site for power generation.

Results show coal production and usage to rise over 500 MT in the year 2010. This would require a rapid expansion of the coal transportation and distribution system. In 1989/90, the railways carried 135 MT of coal which constituted 42% of the total freight transported by the railways. This capacity would need to be expanded along with other infrastructural aspects, such as ports, etc.

#### 9.2.4 Power

The power sector, apart from problems of indigenisation of equipment, poor quality coal supply and restricted pricing powers, etc. is essentially overburdened in relation to its managerial capabilities and infrastructure. The industry, therefore, requires an inflow of superior managerial expertise, which can be achieved through the involvement of the private sector. This would also bring in larger financial resources for the electric utility industry. Imbalances in low investments for transmission and distribution facilities also need to be corrected early to ensure proper utilisation of generating capacity, and minimising T&D losses nationally.

The government has recently announced some specific steps for involvement of the private sector in power generation, but these are likely to have limited success. The private sector is unlikely to seek business opportunities in this sector, if it is tied down to the state electricity boards as its main customer. Unless an entire region is thrown open to the private sector for generation, transmission and distribution, private capital and enterprise are unlikely to enter this sector in a big way. Since the gap between electricity demand and installed capacity is growing, early steps are essential for attracting private capital into the power sector.

## Rural energy sector

Three-fourths of the Indian population are in the rural areas and meeting their energy requirements is an enormous task. Traditionally rural people have depended on biofuels for their energy needs at a 'zero private cost'. However, increasing pressure on the environment due to various factors including rapid population growth has necessitated the need for finding cost effective and environmentally sustainable energy alternatives. Substitution of biofuels by more superior commercial fuels appears limited in the foreseeable future, primarily due to the low purchasing power of the rural population and relatively limited market penetration. Consequently, the focus needs to be on the following:

- (1) Enhancement of energy supply options such as afforestation and wastelands development which are also environmentally sound.
- (2) Dissemination of biomass based efficient technologies like biogas plants, briquetting, improved cookstoves, etc.

However, the implementation of rural energy programmes in the past has suffered from several limitations. These may be overcome by the following measures.

- (1) Energy development strategies need to be integrated with the overall development planning at a decentralised level so that the development priorities of the people are taken into account.
- (2) The dissemination of any technology should not be done in isolation but as part of an energy system. Therefore, one would need to look at energy supplies and demands at a localised level. This warrants a 'bottom-up' approach.
- (3) The research and development activities in appropriate technologies should be location-specific. Also the training needs required for successful implementation of the energy programmes should be carefully identified and the training imparted.

To summarise, it is clear that energy and environmental planning has to be closely integrated in the country if human welfare is to be maximised and resources used in the energy sector are to be directed at optimal choices. The first prerequisite for this would be the setting up of an organisation for energy strategy formulation and planning at the national level. It would perhaps not be desirable to think in terms of an official body to perform this function, but a loosely constituted set-up consisting of senior representatives from government departments, research institutions and the major



energy supply organisations could serve as an effective body for evolving and monitoring national energy plans and their implementation. The Ministry of Environment and Forests would have to be an important and effective part of this set up. The secretariat facilities and analytical work for this loosely structured body should preferably be outside the government, so that adequate academic, research and intellectual inputs could be effectively mobilised to provide direction and shape to future energy policy and plans. The organisation could be given the title of National Energy Policy Committee, and its work should be visible and debated openly on a continuing basis.

The problems of energy pricing, environmental protection and local effects of energy decisions are so closely interrelated, that they require comprehensive treatment at a decentralised level throughout the country. It is clear that an overcentralised approach to energy planning taking into account environmental considerations would not only be cumbersome and tardy, but also likely to ignore optimality on a local and regional basis. It would, therefore, be essential to bring into existence regulatory commissions at the regional level which are empowered to arrive at pricing decisions as well as environmental actions related to the establishment of energy projects. These commissions should deal with energy across the board ranging from the coal mines to power plants, refinery facilities and large distribution facilities which may have environmental implications. Pricing issues are critically important in the implementation of environmental protection plans. It has been seen, for instance, that the establishment of coal washing facilities in the country, even when economically justified to the fullest measure, have not been implemented because of differences between the coal and power industries on sharing of the costs involved. The regulatory commission proposed should be empowered to come up with decisions on such issues, which would be binding on the parties concerned.

At a micro level the integration of energy and environmental planning can be achieved most effectively through a coordinated training approach, whereby energy professionals are appraised of environmental implications and issues while those dealing with environmental protection and standards are trained in the economics of environmental protection, wherein the trade-offs involved in control regimes and measures are the guiding principles as against treating standards as absolute on the basis of technical considerations.

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